PRATT & WHITNEY
R985AN-1, 3,39,39A
SERVICE INSTRUCTIONS
1-2R-R985-2

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DEPARTMENT OF THE ARMY TECHNICAL MANUAL

SERVICE INSTRUCTIONS

MODELS R-985-AN-1, -3, -39, AND -39A ENGINES

HEADQUARTERS, DEPARTMENT OF THE ARMY

FEBRUARY 1961

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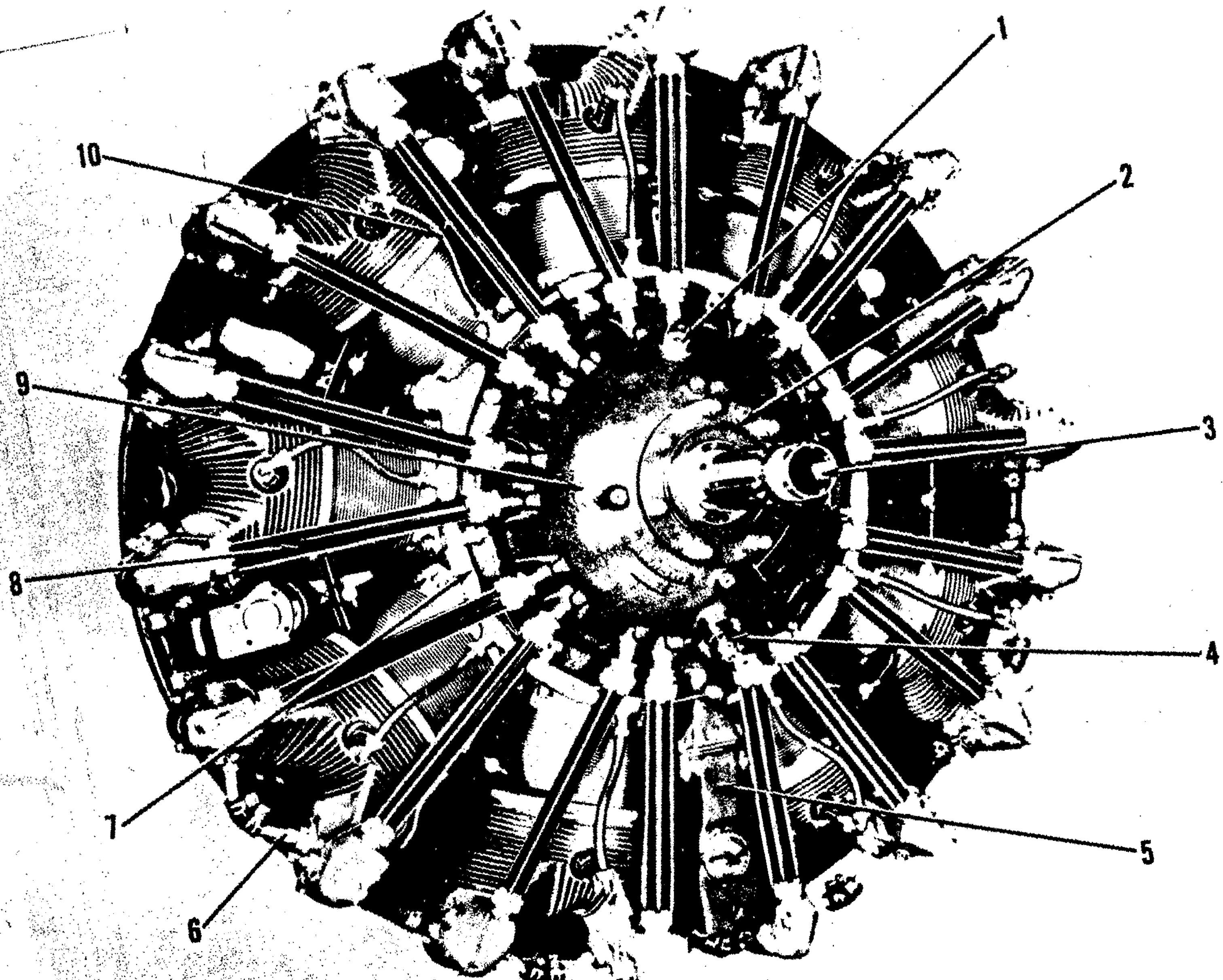

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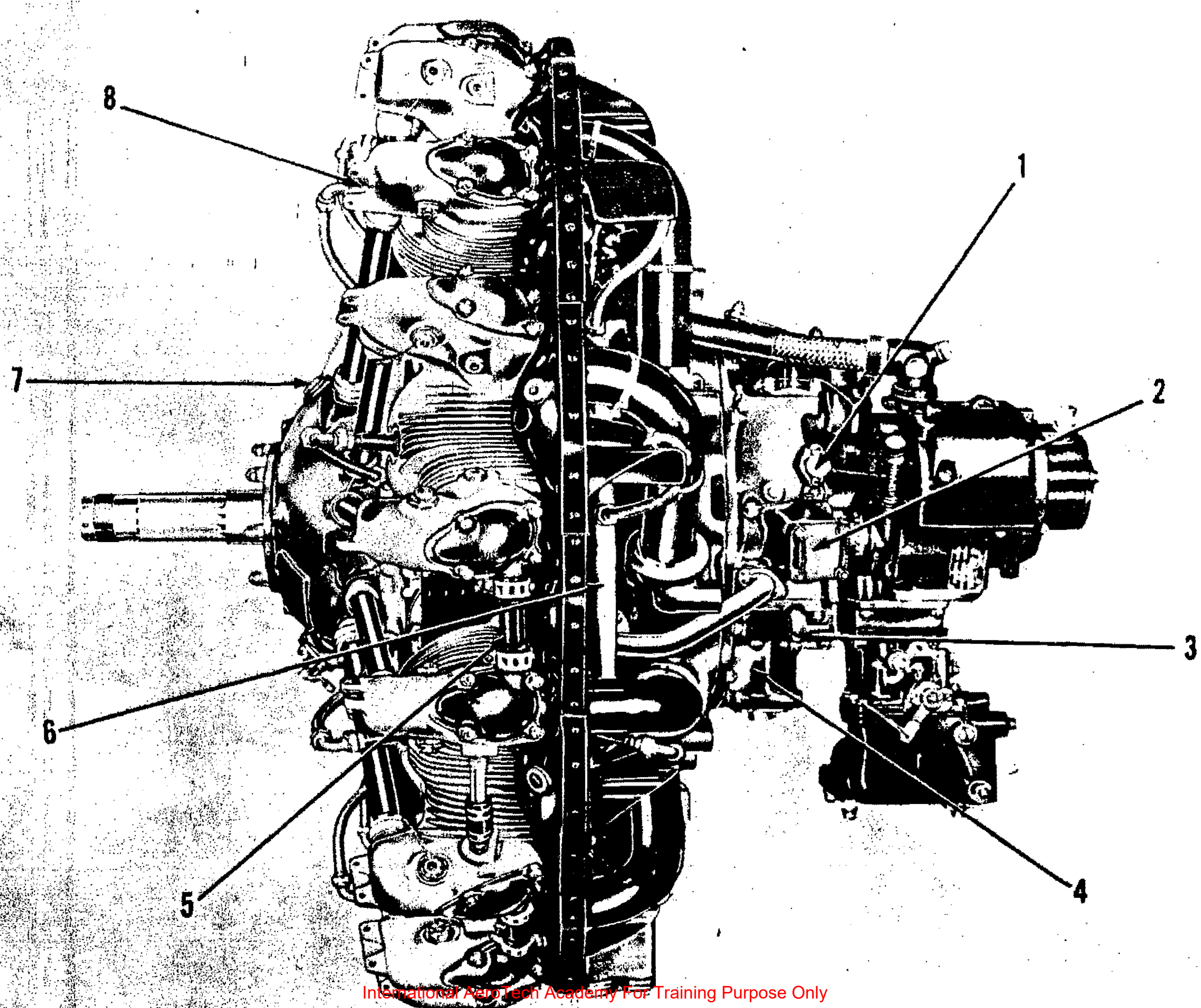


Figure 2. Side View of Engine

SECTION I
INTRODUCTION

1—1. GENERAL.

1—2. This publication comprises the Service Instructions for the Model R-985-AN-1 and Associated Models -AN-3, -39, and -39A engines, designed by Pratt & Whitney Aircraft Corp, East Hartford, Connecticut.

1—3. Any instructions in this publication which are in conflict with effective BuAer Bulletins, Changes, Technical Notes, Technical Manuals, or other BuAer or Army directives shall be superseded by the instructions contained in the later publications.

1—4. DIRECTIONAL REFERENCES.

1—5. Right and left, clockwise and counterclockwise, upper and lower, and similar directional references apply to the engine as viewed from the rear with the crankshaft in the horizontal position and with No. 1 cylinder at the top of the engine. The normal direction of rotation of the crankshaft is clockwise. In the case of accessory drives, the direction of rotation is specified as it appears to an observer facing the accessory mounting pad.

1—6. SPECIFICATIONS.

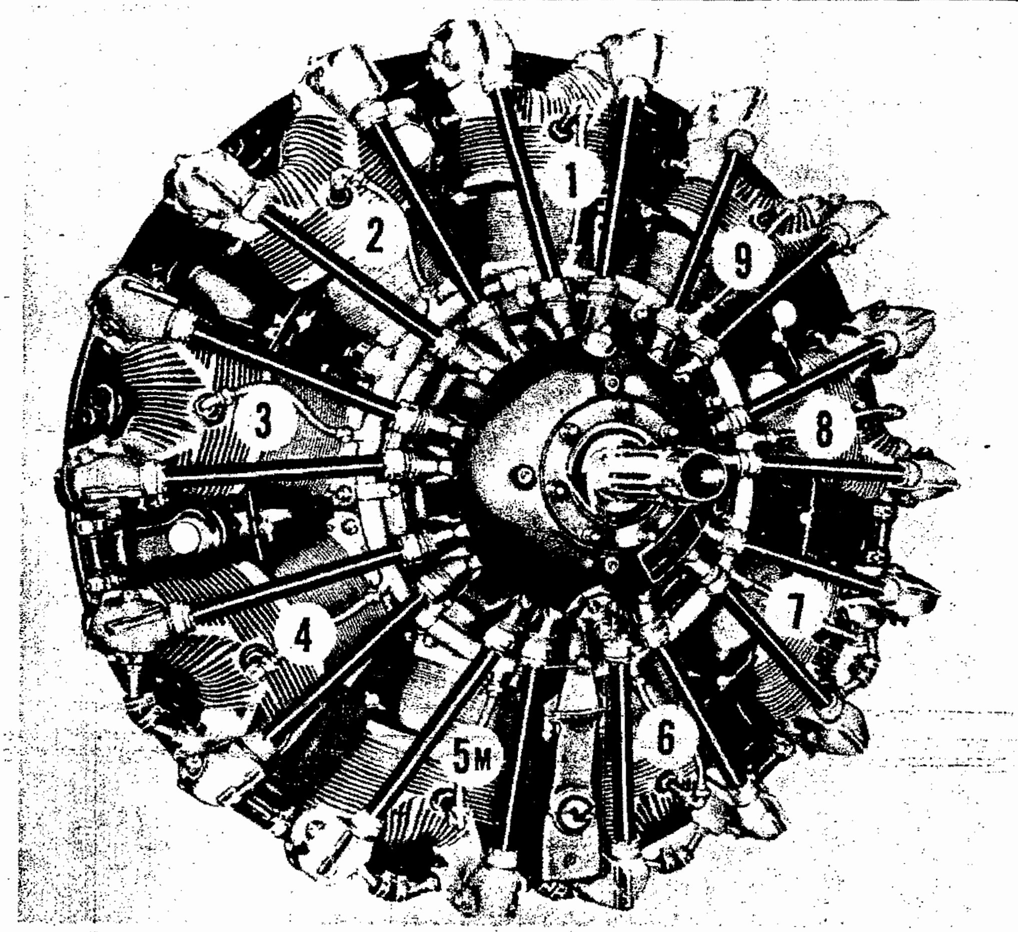
1—7. Where specification numbers are given for materials, the basic specification numbers shall be interpreted to include the latest revisions, supplements, and amendments thereto.

1—8. CYLINDER NUMBERING.

1—9. Beginning with the top cylinder, the cylinders are numbered consecutively in the direction of crankshaft rotation. Cylinder numbering, firing order, and the position of the masterod is illustrated in *[Figure 1—1]*.

1—10. FIRING ORDER.

1—11. The firing order for the R-985 aircraft engine is as follows: 1-3-5-7-9-2-4-6-8 as viewed from the rear of the engine *[Figure 1—2]*.



FIRING ORDER
1-3-5-7-9-2-4-6-8
M = MASTER CYLINDER

Figure 1—1. Cylinder Numbering and Firing Order

INDEX TO FIGURE 1—2

1. Intake Pipe
2. Breather
3. Right Magneto
4. Oil Pressure Relief Valve
5. Scavenge Oil Pipe
6. Oil Pump
7. Oil Sump
8. Carburetor
9. Oil Outlet Port
10. F/A Mixture Temperature Connection
11. Left Magneto
12. Swivel Breather
13. Engine Mount Boss
14. Engine Primer Distributor

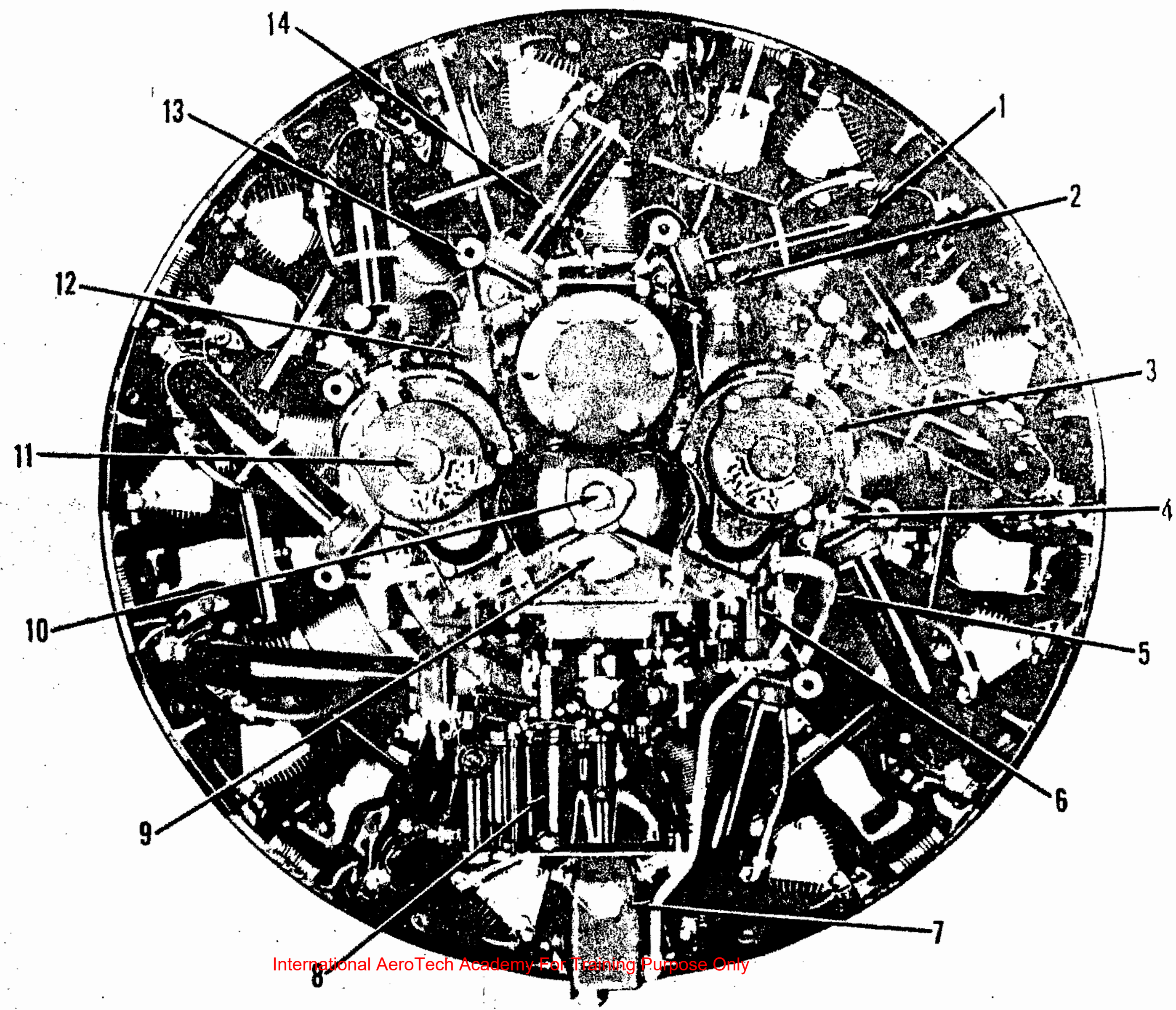


Figure 1—2. Rear View of Engine

SECTION II

GENERAL DESCRIPTION

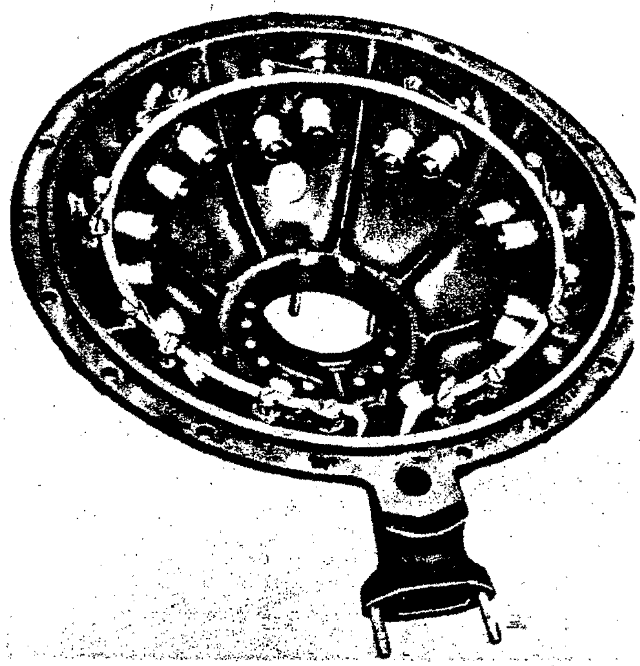


Figure 2–1. Front Case

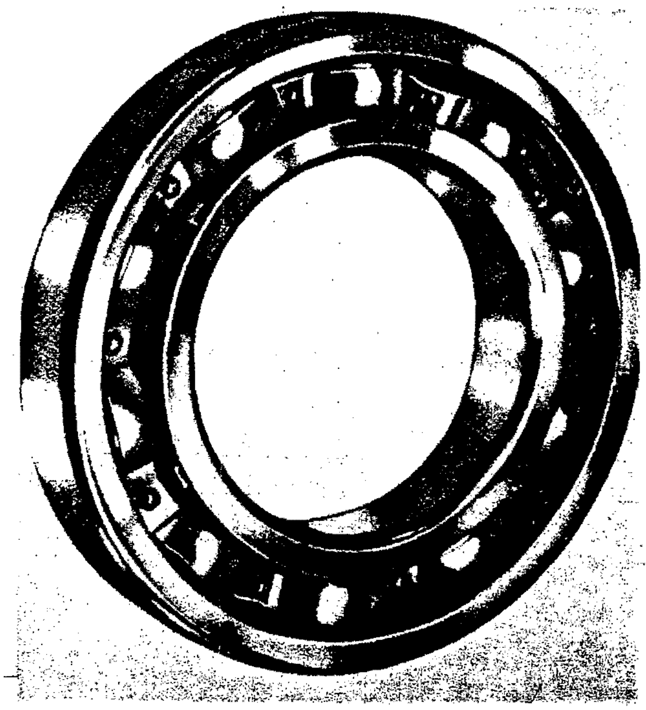


Figure 2–2. Thrust Bearing

2–1. GENERAL.

2–2. The model R-985-AN-1 engines and associated models are direct drive, nine cylinder, single row, radial, aircooled engines with built-in superchargers. The Table of Specifications, Section III, indicates slight variations existing among the different model engines. The model R-985-AN-1 engine is used for the purpose of general description.

2–3. The engine is divided into five sections, the Front Section, Crankcase Section, Cylinders, Supercharger Section, and the Rear Section. The crankcase is made of forged aluminum alloy, whereas the front, supercharger, and rear cases are made of either magnesium alloy or aluminum alloy. The following table lists the engine models having magnesium alloy cases and those having one or more aluminum alloy cases.

Models Having Magnesium Front, Supercharger, and Rear Cases	Models Having One or More Aluminum Cases
R-985-AN-1	R-985-AN-3
R-985-AN-39	R-985-AN-39A

2–4. FRONT SECTION.

2–5. The front section is an aluminum or magnesium forging *[Figure 2–1]*. It supports a deep groove ball bearing *[Figure 2–2]* which transmits the thrust of the propeller from the crankshaft to the engine mount. This thrust is transmitted by way of the crankcase. The crankshaft is located in the thrust bearing by means of the thrust bearing spacer. A rocker oil manifold ring in the front section is part of the rocker lubricating system. The R-985 engine incorporates tubing in the front case for operation of a hydro-controllable propeller and either a control valve (for the two position propeller) or

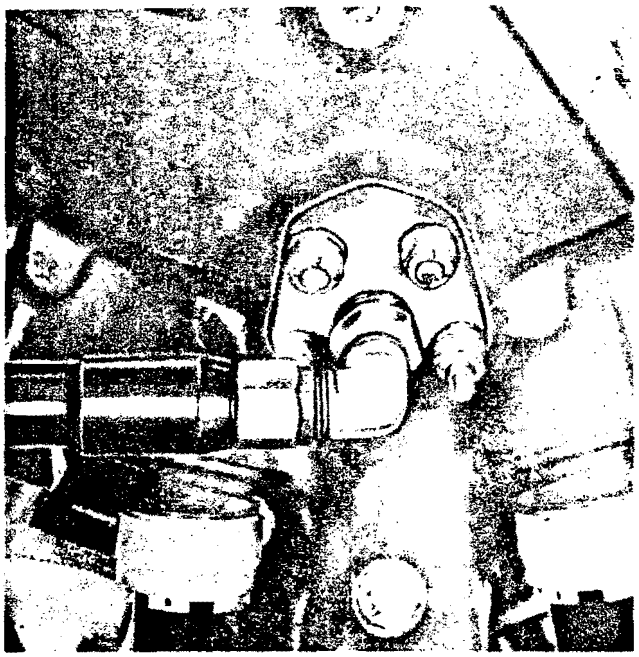


Figure 2–3. Propeller Control Tubing

a plug with an oil transfer tube *[Figure 2–3]* for the con stant speed or hydromatic propeller.

2–6. CRANKCASE SECTION.

2–7. The crankcase is divided into two sections *[Figures 2–4 through 2–6]*. These sections are held together by nine crankcase bolts located between the cylinder pads. Two main bearings, located in the crankcase front section and rear section respectively, support the crankshaft. The two sections of the crankcase are machined together. A rubber seal is used between each cylinder flange and the crankcase. The cam is supported on the cam drive gear. The tappets and tappet guides are mounted in bosses which are an integral part of the front section.

2–8. CYLINDERS.

2–9. The cylinders are of steel and aluminum construction *[Figure 2–7]*. The cylinder barrels are machined from steel forgings and have cooling fins which are an integral part of the barrel. The cylinder head is made of aluminum and has closely spaced cooling fins cast as an integral part of the cylinder head. Each cylinder has one inlet valve and one exhaust valve. The inlet valve is seated on a bronze insert; the exhaust valve is seated on a steel insert. Both inserts are shrunk into the head casting. The proper cooling of the exhaust valve seat and stem is of great importance in an air-cooled engine. Fins are concentrated on the top and on the exhaust side of the hemispherical head and around the exhaust port. These are the areas where it is essential to have the greatest amount of heat dissipation.

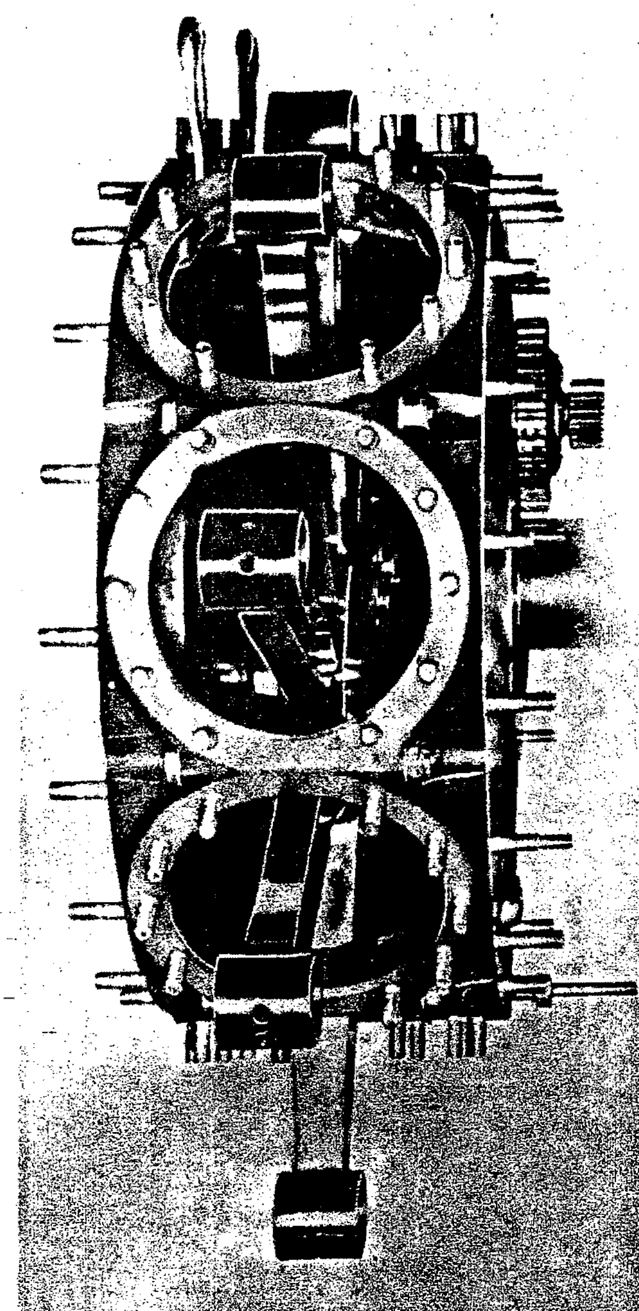


Figure 2–4. Crankcase Section

2–10. CYLINDER BAFFLES.

2–11. Pressure type deflectors are standard equipment. Pressure baffling forces a high velocity flow of cooling air through and over the fins on the cylinders, the propeller builds up a positive pressure in front of the engine cylinders and a negative pressure in the rear of the cylinders. Pressure baffles have the advantage of more efficient cooling with less volume of cooling air flowing, thus improving the performance of the engine.

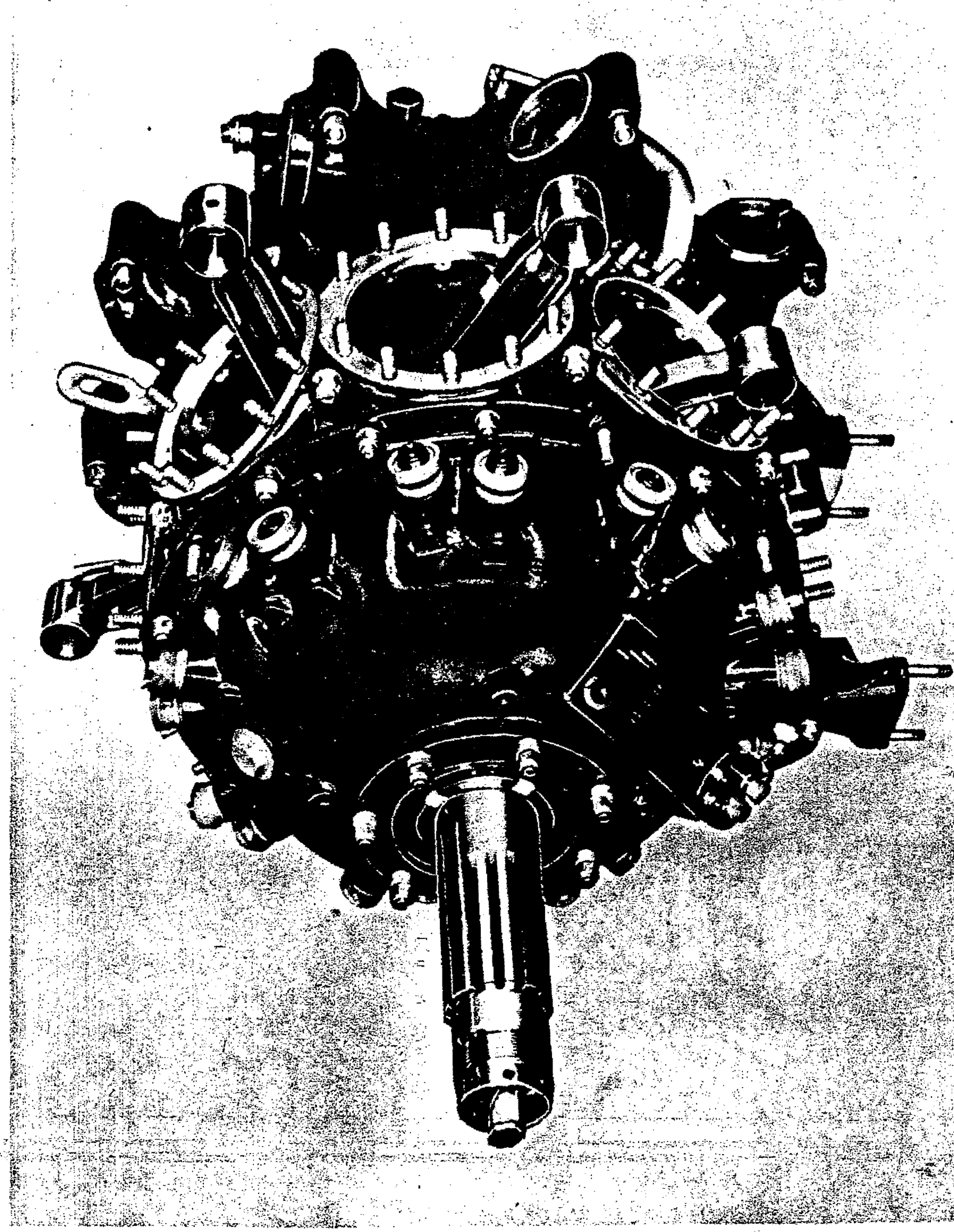


Figure 2—5. Front and Crankcase Section

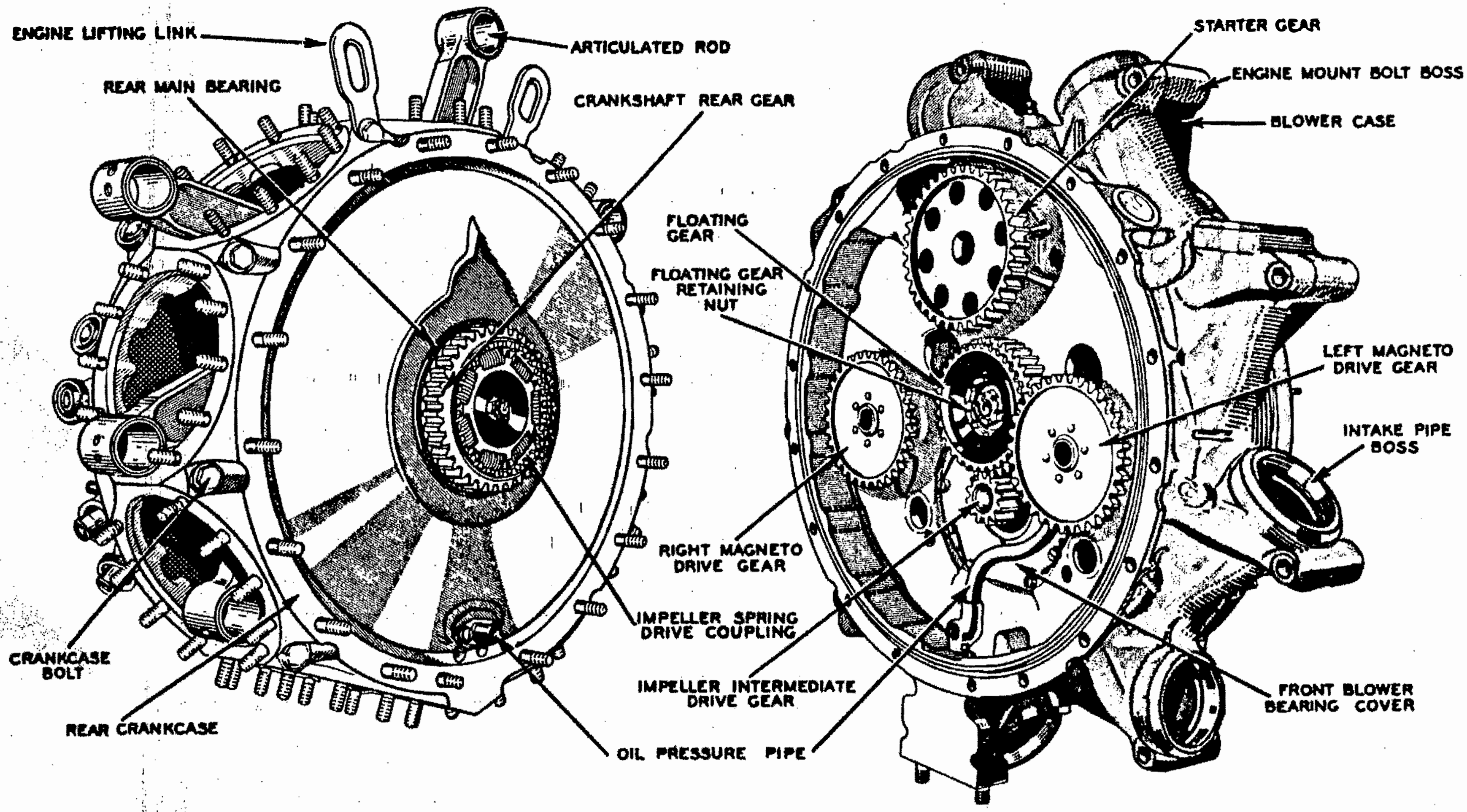


Figure 2—6. Front Crankcase and Supercharger Section

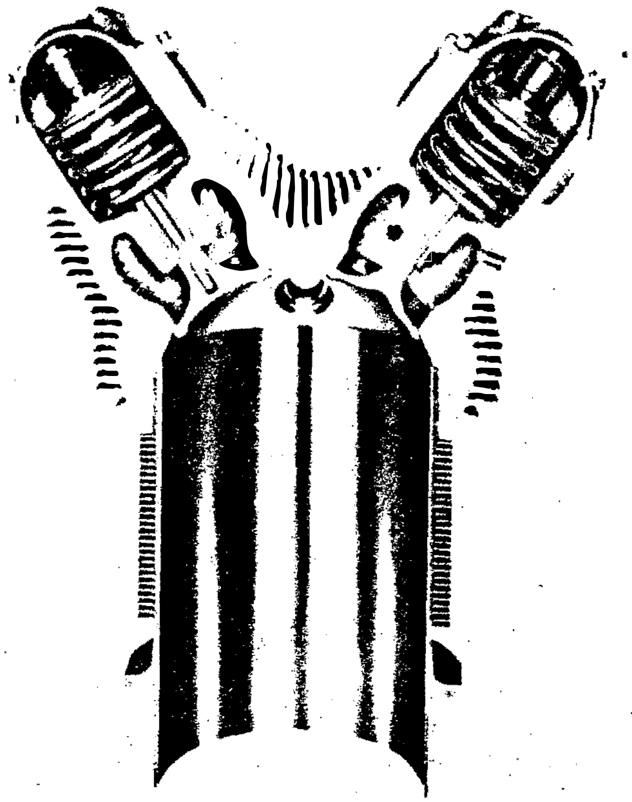


Figure 2—7. Cutaway of Cylinder

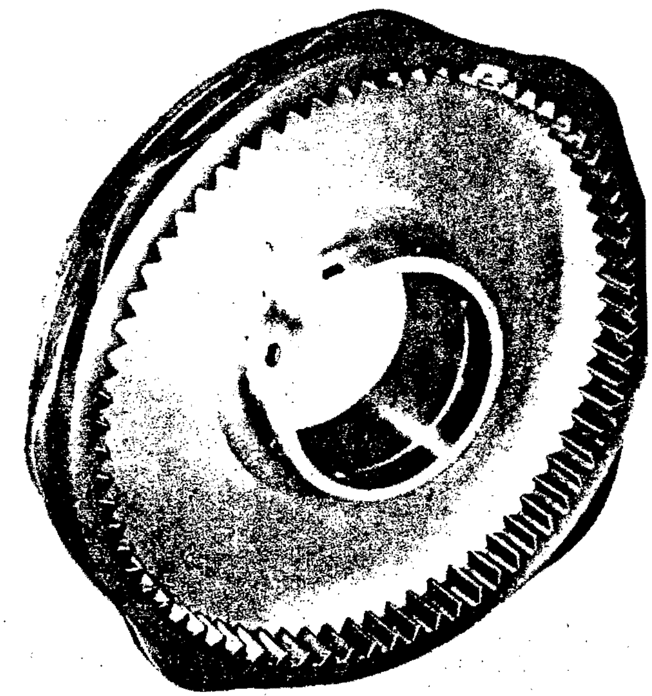


Figure 2—8. Rear View of Cam

2—12. VALVE MECHANISM.

2—13. All valve operating parts are enclosed. The rockers are supported by a double row ball or roller bearings, located in the rocker. Eighteen tappets located in the front section actuate the rockers through tubular pushrods which have hardened steel ballends. These rods are enclosed in removable, oil tight, cover tubes held in place by a nut, seal and packing at the top and bottom. The rockerbox covers are secured by studs and lock nuts. A valve clearance adjusting screw is in the end of the rocker over the valve stem. A half ball is used between the adjusting screw and the valve stem to minimize the friction at this joint.

2—14. Two concentric valve springs are used on each valve. They are secured to the valve stem by a split cone and washer. To prevent the possibility of the valves being dropped into the cylinders while the split cones are being installed or removed, a snapring is installed on each valve. The inlet valves are solid whereas the exhaust valves are hollow and are sodium filled for cooling. The sodium turns to liquid form during engine operation due to the heat of the exhaust, and dissipates some of the heat assimilated by the exhaust valve in operation. A stellite face prolongs the life of the seating surface of the exhaust valve.

2—15. The entire valve mechanism is pressure lubricated. Oil enters the tappets through the guides, thence through the pushrods and rockers. The rockerboxes of the lower cylinders, are interconnected and drain into a separate compartment of the sump. An additional scavenge stage in the oil pump completes the circulating system. This fully automatic lubrication makes possible greatly extended operating periods.

2—16. TIMING GEAR.

2—17. By means of a train of spur gears and internal teeth in the cam ring forging, the cam *[Figure 2—8]* is driven at one-eighth crankshaft speed. It rotates in the opposite direction from the crankshaft. The cam actuates all valves through two four-lobed tracks. It rotates on the cam drive gear. The cam reduction gear is driven

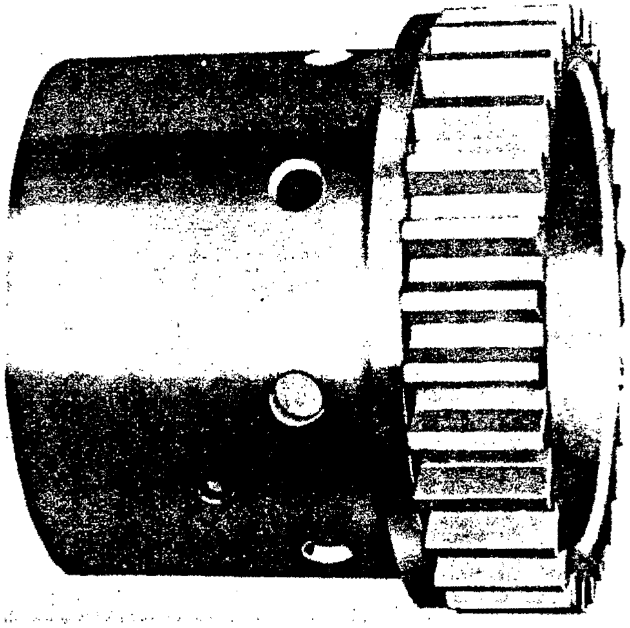


Figure 2—9. Cam Drive Gear

by the cam drive gear *[Figure 2—9]* and is mounted wit a bearing on each side. This assures perfect alignment.

2—18. CRANKSHAFT.

2—19. The crankshaft *[Figure 2—10]* is of a singl throw, two-piece, split pin type supported on thre bearings. There is a roller bearing on each side of th throw. These roller bearings are supported in the cranl case. There is a ball bearing in the front section whic takes the propeller thrust as well as the radial load.

2—20. Two oil jets, one located in the front sectio rear plug, and the other on the top of the rear cheel furnish lubrication to the pistons, pistonpins, and cylin ders, in addition to the oil thrown off the masterod an linkpin bushings.

2—21. The weights of reciprocating and rotating part connected to the crankshaft are counterbalanced b weights which are riveted to the cheeks of the crank shaft *[Figure 2—11]*. The crankshaft is balanced stati cally and dynamically against a master balance weight Two flyweights in the rear counterweight suppress tor sional vibrations developed by power impulses.

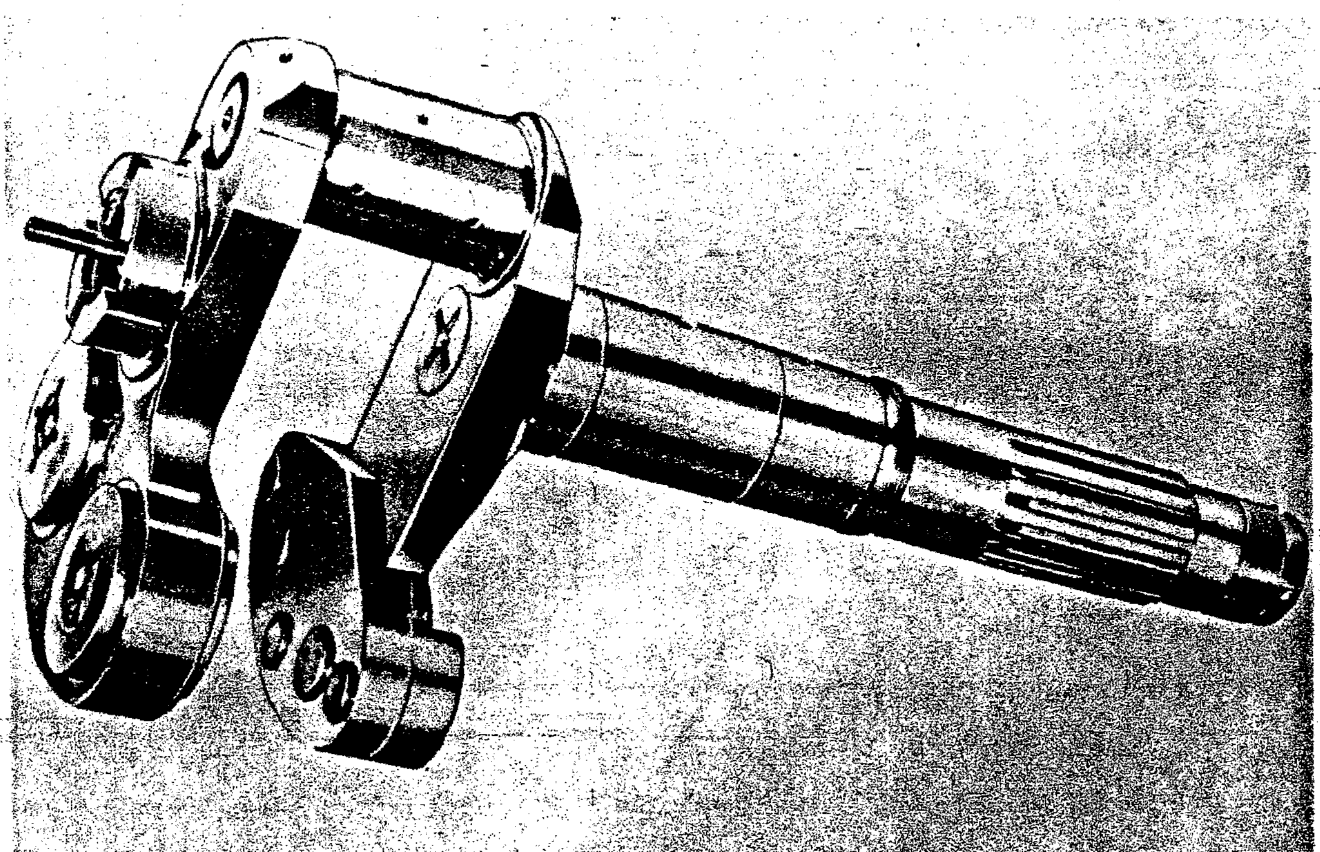


Figure 2—10. Crankshaft

Figure 2—11. Counterweight

2—22. LINKRODS.

2—23. The masterod *[Figure 2—12]* is of one-piece construction and incorporates a shrunk-in steel backed leaded silver bearing. Eight "I" section linkrods are attached to the masterod by means of linkpins, fitted tightly in the masterod. Each linkrod is bronze bushed for the pistonpins and linkpins. Oil carried under pressure to the crankpin, lubricates the masterod-bearings and also the linkpins through drilled passages. The pistonpin bushings are lubricated by the oil thrown off by the masterod linkpin bushings, and oil jets.

2—24. PISTONS.

2—25. Each piston *[Figure 2—13]* is machined from an aluminum-alloy forging. Each has five ring grooves and is of the full skirt type. The top three grooves on each piston carry compression rings. The top compression ring is chromium plated on the face which bears against the cylinder wall. The fourth groove carries dual oil control rings and the fifth or bottom groove carries a scraper ring. The pistonpin floats in the pistonpin bosses and the linkrod bushing.

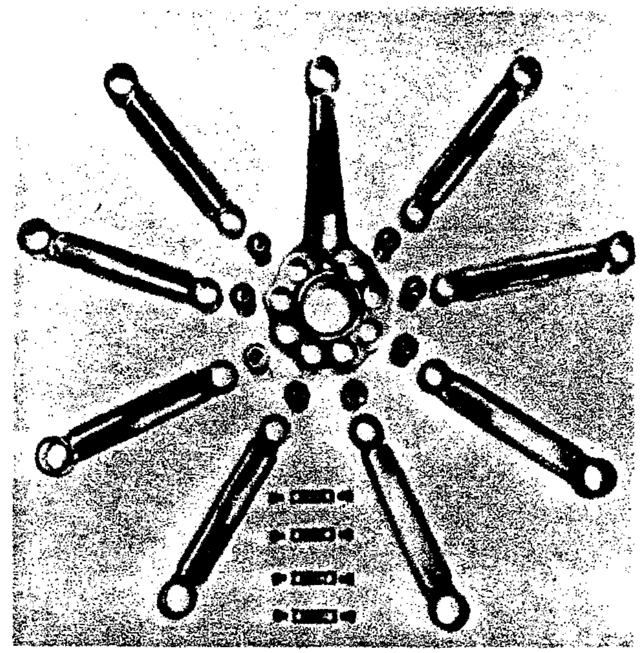


Figure 2—12. Masterod, Linkrod, and Related Parts

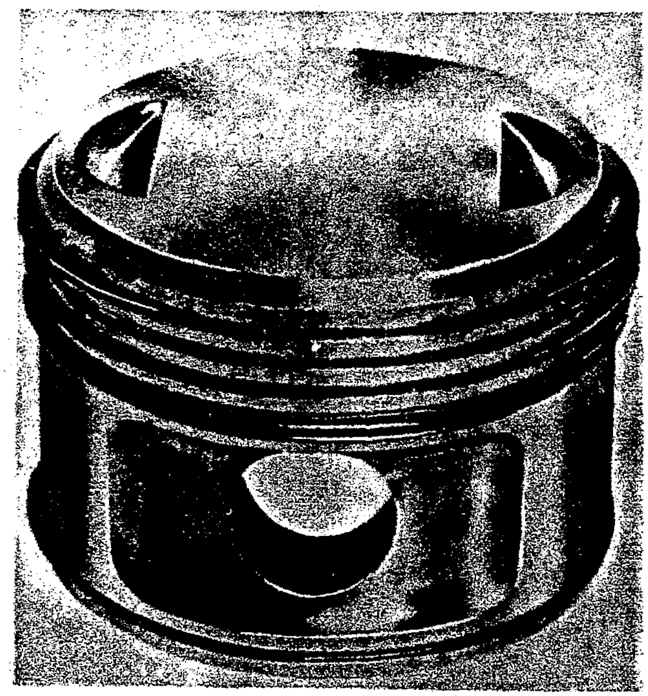


Figure 2—13. Piston and Rings Assembly

2—26. OIL SUMP.

2—27. The oil sump is located between cylinders No. 5 and No. 6. One end of the sump is connected to the front section, the other end is connected to the supercharger section. Oil is scavenged by first stage of the oil pump.

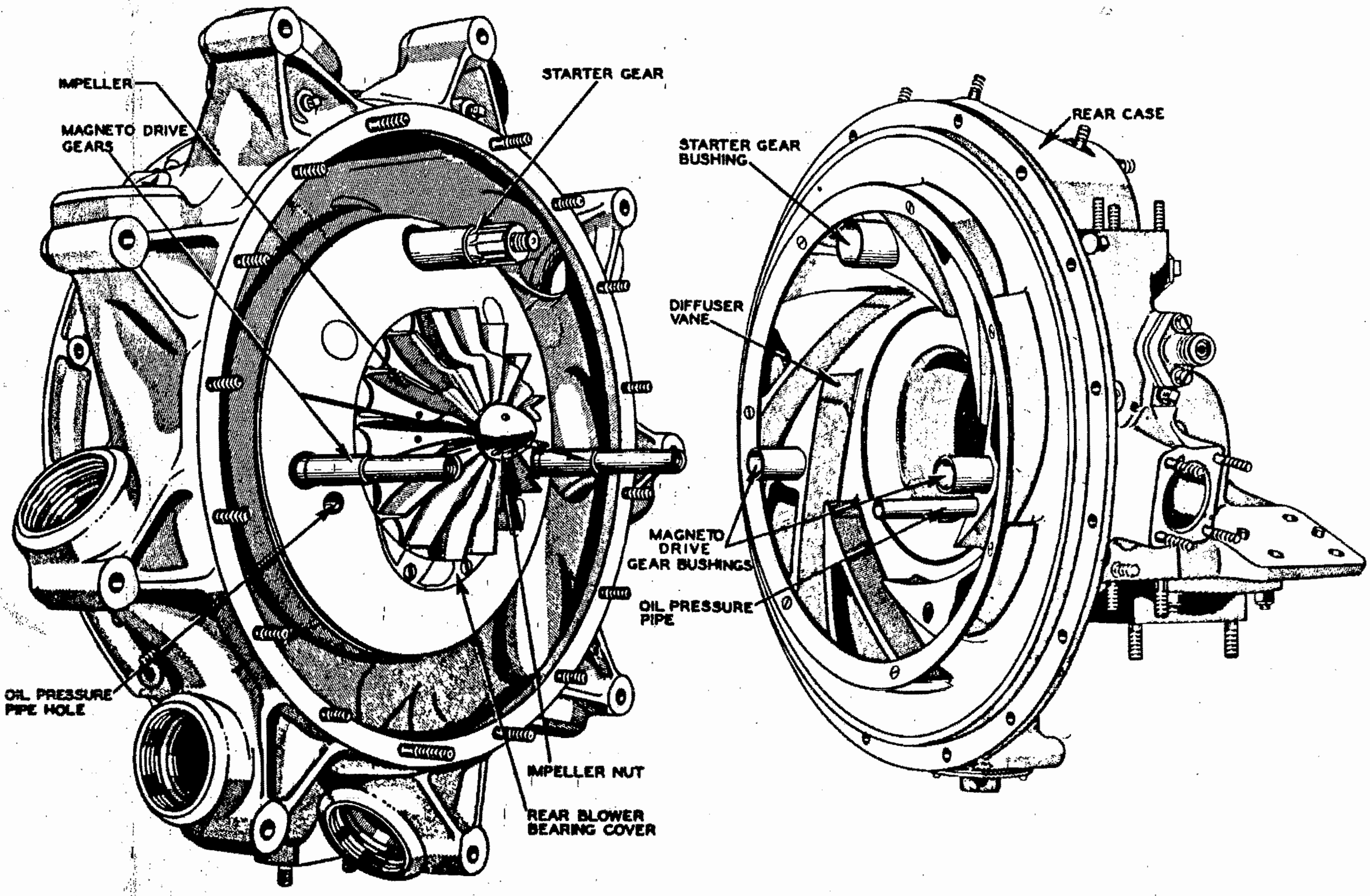
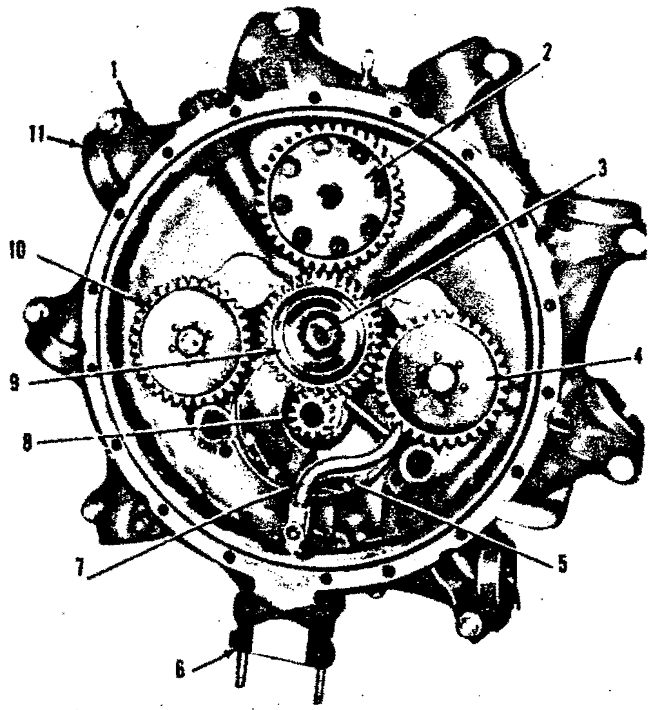


Figure 2—14. Supercharger and Rear Cases



1. Supercharger Case
2. Starter Gear
3. Floating Gear Retaining Nut
4. Left Magneto Drive Gear
5. Supercharger Front Bearing Cover
6. Oil Sump Rear Mount
7. Pressure Oil Tube
8. Impeller Intermediate Drive Gear
9. Floating Gear
10. Right Magneto Drive Gear
11. Intake Pipe Boss

Figure 2—15. Front View of Supercharger Case

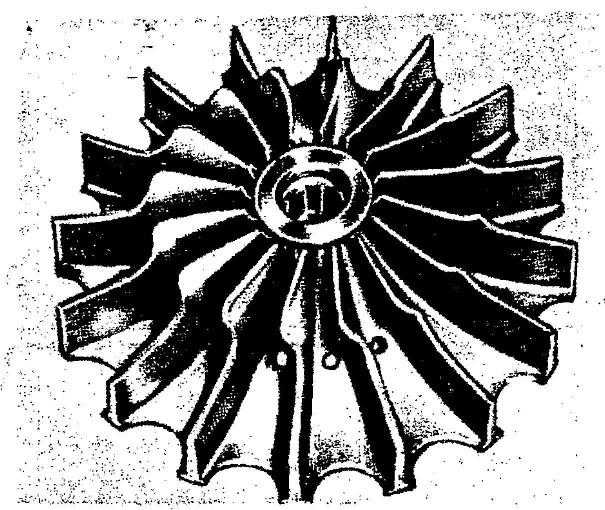


Figure 2—16. Impeller

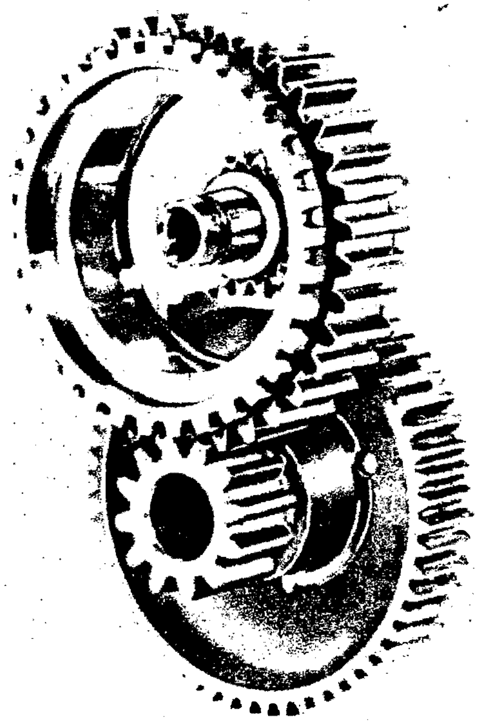


Figure 2—17. Impeller Gear Train

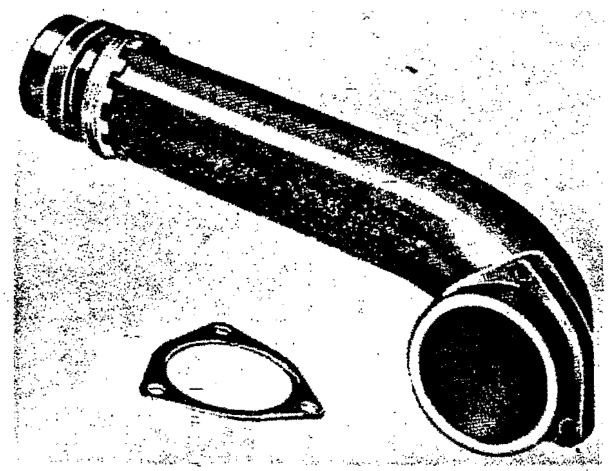
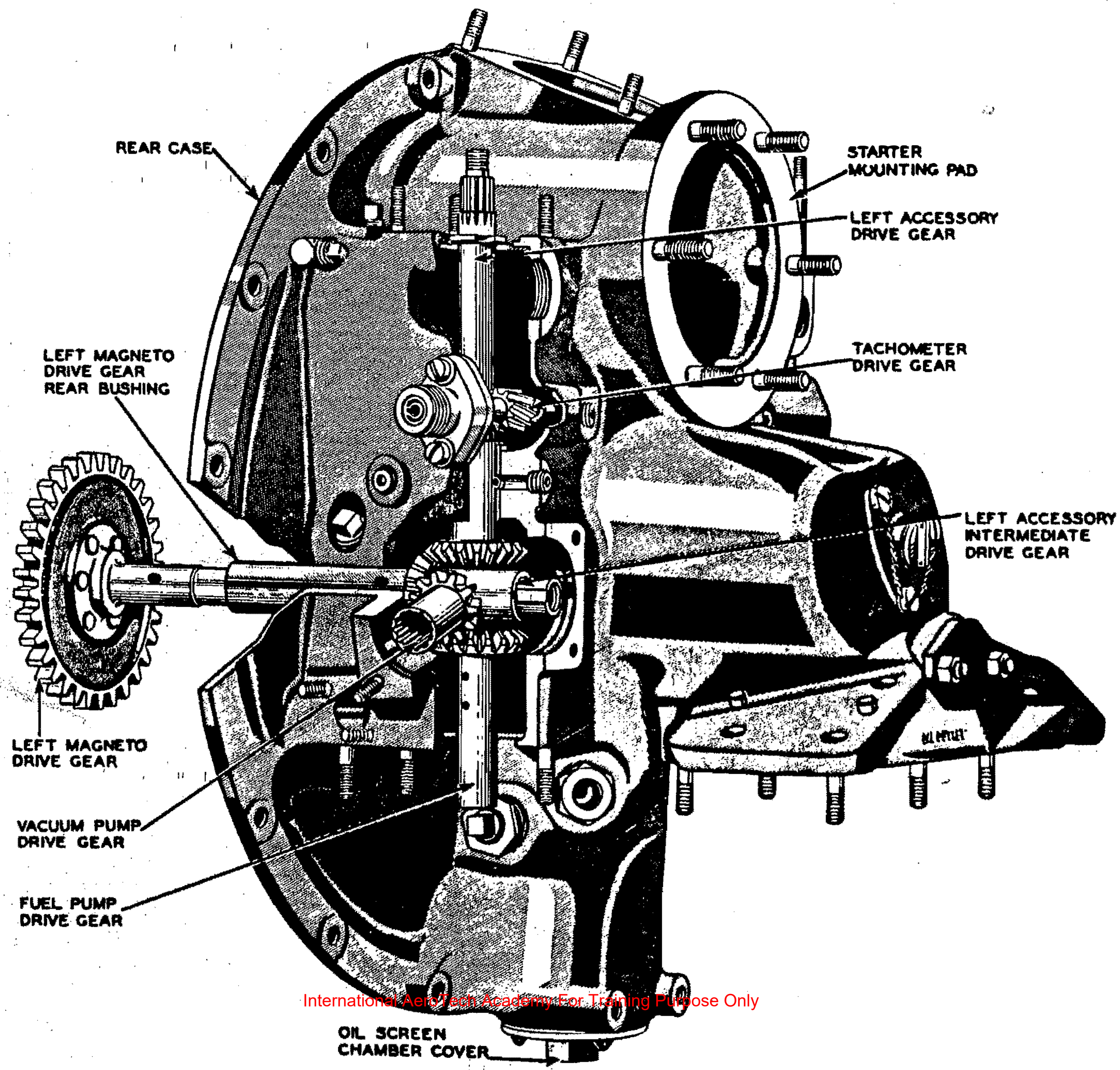


Figure 2—18. Intake Pipe and Related Parts

2—28. SUPERCHARGER SECTION.

2—29. The supercharger section ***[Figures 2—14** and **2—15]***, or what might be called the mounting section, supports the engine in the aircraft. It is attached to the crankcase rear section. The impeller ***[Figure 2—16]***, and its gearing ***[Figure 2—17]*** are carried in this case. An annulus in this section receives the mixture from the impeller through a diffuser chamber. The mixture is delivered to the cylinders through tangential intake pipes ***[Figure 2—18]***.


REAR CASE
STARTER MOUNTING PAD
LEFT ACCESSORY DRIVE GEAR
LEFT MAGNETO DRIVE GEAR REAR BUSHING
TACHOMETER DRIVE GEAR
LEFT ACCESSORY INTERMEDIATE DRIVE GEAR
LEFT MAGNETO DRIVE GEAR
VACUUM PUMP DRIVE GEAR
FUEL PUMP DRIVE GEAR
OIL SCREEN CHAMBER COVER

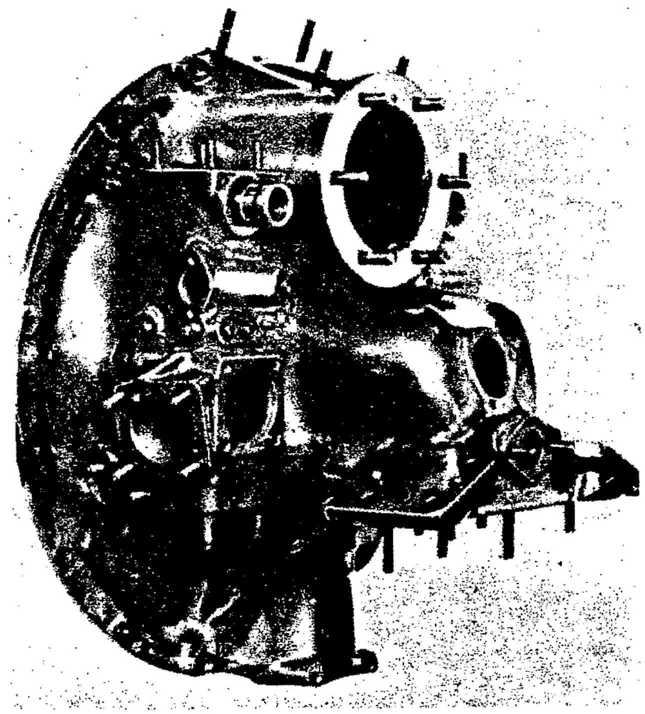


Figure 2—20. Rear Case

2—30. The impeller is of the high-speed centrifugal type having a 10:1 supercharger ratio. The impeller is driven from the crankshaft by means of a spring coupling located inside the rear crankshaft gear. This gear drives a floating gear in the supercharger section. The impeller is driven at a high rate of speed by a pair of spur gears. The spring coupling relieves the supercharger gears of sudden strains resulting from rapid acceleration or deceleration.

2—31. REAR SECTION.

2—32. The rear section is attached to the supercharger section *[Figures 2—19 through 2—20]*. This section carries the accessories and accessory drives. These include two Scintilla or Bosch magnetos, a Stromberg carburetor, an oil pump, an oil strainer, one or two tachometer drives, and two vertical accessory drives.

2—33. The rear section has air straightener plates in the elbow above the carburetor. These plates direct the mixture evenly to the impeller and to the diffuser vanes located on the forward face of the rear section. These diffuser vanes lead the mixture into the anulus in the supercharger section, from which it is drawn through the intake pipes into the cylinders.

2—34. A check valve is provided in the oil-pressure strainer to prevent oil flow into the engine when the engine is inoperative.

2—35. ACCESSORY DRIVES.

2—36. These accessories are grouped at the rear of the engine *[Figure 2—19]* and are driven by three shafts which extend entirely through the supercharger and rear sections. Each of the three shafts carries a spur gear at its forward end which engages a gear attached to the rear of the crankshaft. The upper shaft provides a drive for the starter. Each of the two lower shafts drives a magneto by means of an adjustable flexible coupling. In addition to these shafts, four vertical drives are provided for by a bevel gear on each shaft. The upper drives are for two auxiliary pumps and two tachometers. The lower vertical shafts drive an oil pump on the right side, and a fuel pump on the left side.

2—37. INDUCTION SYSTEM.

2—38. The induction system feeding air to the carburetor varies with different airplane installations. The gasoline air mixture is taken from the carburetor and passed directly into the rear section. A mixture thermometer opening is provided in the carburetor ell cover to that the temperature of the mixture may be determined.

2—39. CARBURETION.

2—40. GENERAL DESCRIPTION.

2—41. The NA-R9B carburetor [*Figure 2—21*] which is standard on the Wasp Jr., is a single barrel, up-draft carburetor. This relatively simple, venturi type carburetor has a single float, and is equipped with an economizer, manually operated needle valve, type mixture control, accelerating pump, and self-primer *Figure [2—22]*.

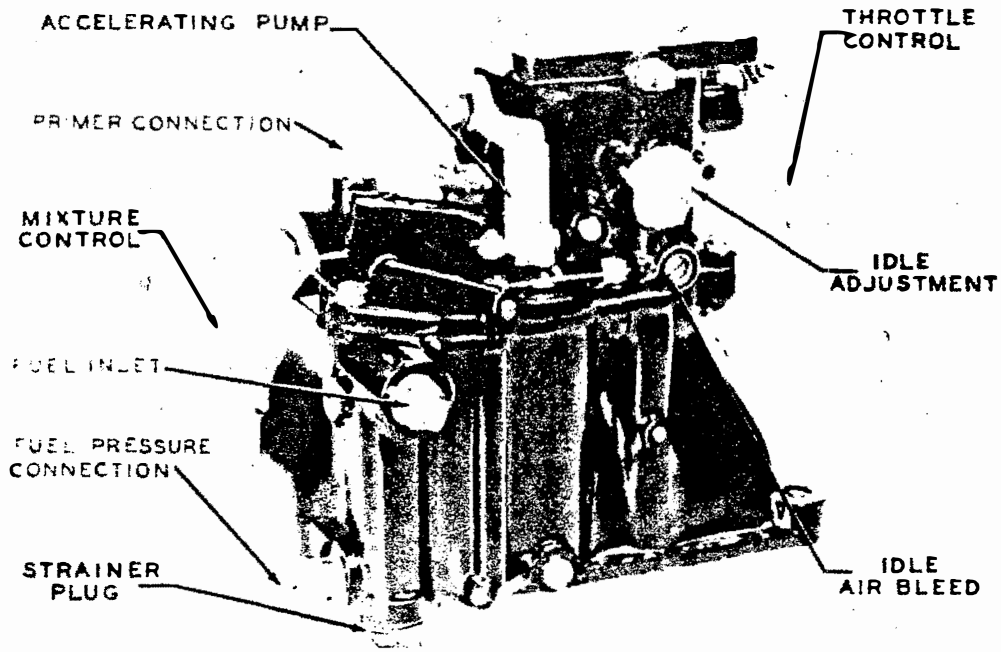


Figure 2—21. Stromberg NA-R9B Carburetor

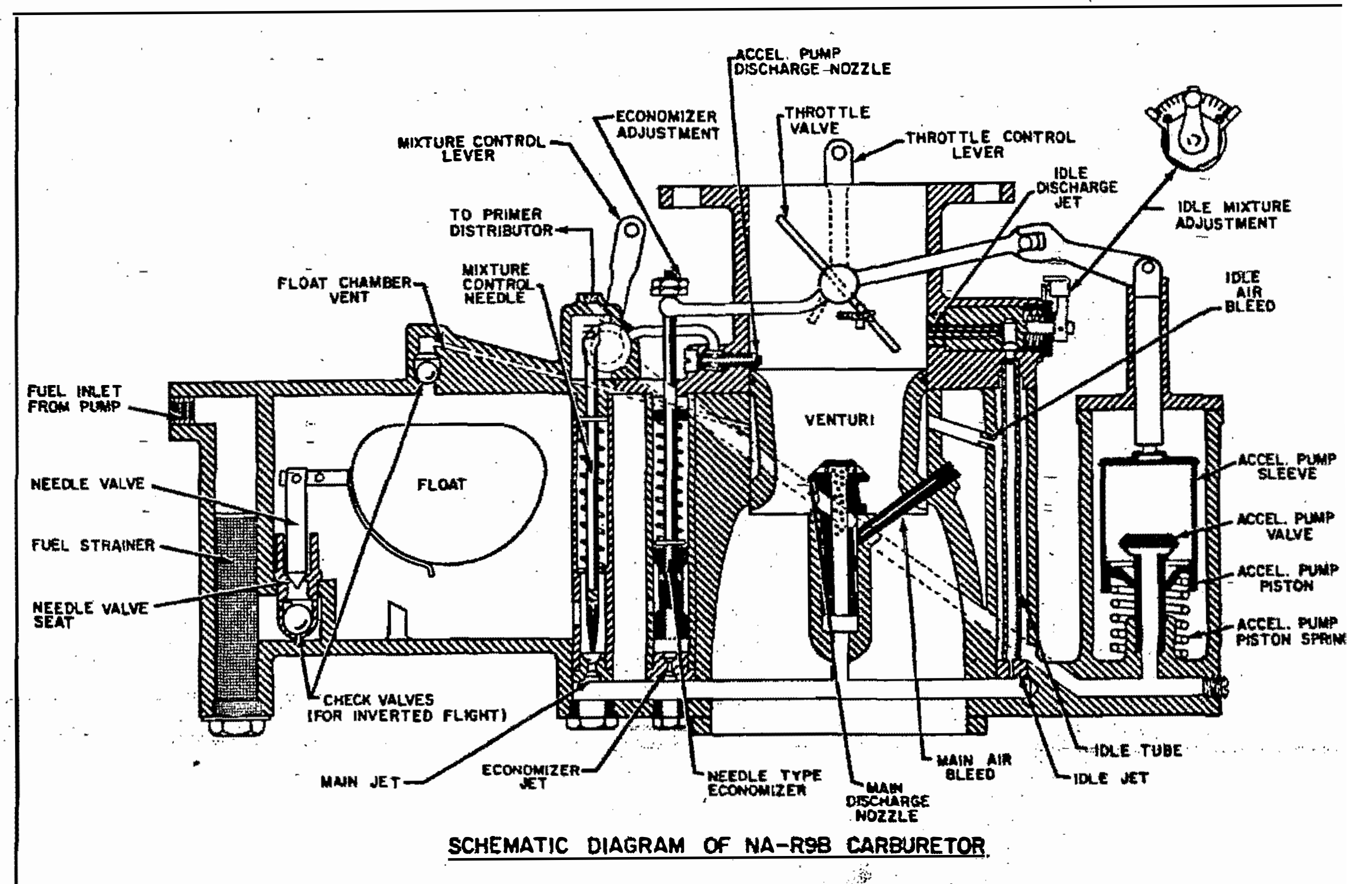


Figure 2—22. Schematic Diagram of Carburetor

2—42. MAIN METERING SYSTEM.

2—42A. The main metering system consists of a venturi, main jet, main air bleed, and a discharge nozzle. It is fortunate that the pressure differential in a venturi varies as the square of the velocity thru it while the fluid flow thru a fixed orifice varies as the square root of the pressure drop across it. Thus, theoretically, the fuel flow thru a simple carburetor will vary directly as the velocity of the air thru the venturi, and if the density of the air is maintained constant in the venturi, the fuel flow will theoretically vary directly as the mass air flow. Actually, this theoretical condition does not strictly hold true, but the fuel flow increases at more rapid rate than the increase in mass air flow. To correct this condition and assist in the vaporization of the fuel as it leaves the carburetor, Stromberg uses the principal of bleeding air into the fuel as it enters the discharge nozzle. This air bleed is known as the main air bleed and is a jet, bleeding air into the main discharge nozzle passage. Such a jet provides a constant F/A ratio throughout the useful range of airflows required by the engine. The fuel-air ratio can be modified as desired by the proper selection of the dimensions of the air bleed, main jet, and discharge nozzles.

2—42B. IDLE SYSTEM.

2—42C. It is necessary to have an idling system to take care of the engine at lower speeds. During idling, the air velocity through the main venturi is very low and there is not sufficient venturi suction to draw fuel from the discharge nozzle. At the same time, however, there is a very high suction on the intake manifold side of the throttle and, therefore, the fuel feed is arranged to deliver into this region of high suction. To utilize this suction, a complete discharge jet system in miniature is used with the fuel metering jet, air bleed, and discharge jet, opening into the small air passage around the throttle, formed by the slot in the idling discharge jet. Idling adjustment is accomplished by adjusting the idle discharge nozzle in connection with the throttle valve opening.

2—42D. ECONOMIZER.

2—42E. It is desirable to have a lean mixture for maximum economy at part throttle or cruising speeds, and a much richer mixture for climb and take-off, for the cooling effect at high power. In order to obtain this change in mixture ratio, as the throttle is opened, various forms of economizer systems are used. These, in their present form, are in reality enrichening devices. The NA-R9B, carburetor economizer consists of a needle valve, which is opened by the throttle at a predetermined throttle position, and permits a quantity of fuel to flow through the economizer jet in addition to that furnished by the main metering jet, to mix with the air in the carburetor.

2—42F. MIXTURE CONTROL.

2—42G. As the airplane ascends to altitude, the atmosphere decreases in pressure and temperature resulting in a decrease in density, the weight of the air charge taken into the engine decreases with the decrease in air density, cutting down the power in about the same percentage. In addition, the mixture proportion delivered by the carburetor is affected, the mixture becoming richer at a rate inversely proportional to the square root of change in air density. In order to compensate for this change in mixture, a mixture control is provided on all Stromberg Aircraft Carburetors. The NA-R9B carburetor uses the needle valve type of mixture control. The needle restricts the flow of fuel to the jets. A small nozzle in the venturi which has a restricted passage leading to the float chamber produces the suction in the float chamber. When the mixture control is in full rich position, the float chamber is vented to the air scoop. As the mixture control is gradually leaned off, the valve closes off the float vent which in turn lowers the float chamber pressure.

2—42H. INVERTED FLIGHT.

2—42J. Float type carburetors are designed to operate satisfactorily during all airplane maneuvers. During upside down flying, the float action reverses. Fuel is pumped to the jets at fuel pump pressure which would cause the carburetors to run very rich. Check valves are used to restrict the flow of fuel to the needle valve and to shut off the float chamber vent. Special fuel and oil systems are required if the airplane is to be operated upside down for a long period of time.

2—42K. ACCELERATOR.

2—42L. For quick acceleration of the engine, a quantity of fuel in addition to that supplied by the main metering system is required. A fuel pump, operated by the throttle has, therefore, been incorporated in the design *[Figure 2—23]*. This pump gives a positive accelerating charge, regardless of the suction existing in the carburetor. It delivers this charge as a momentary spurt of fuel followed by a sustained discharge for a few seconds.

2—42M. SELF-PRIMER.

2—42N. The accelerator pump on all the recent float type carburetors is also used for a primer. When the mixture control is placed in the full lean position, a valve on the mixture control shaft opens, allowing the discharge from the accelerating pump to flow into the engine primer lines.

2—42P. IDLE CUT-OFF.

2—42Q. The idle cut-off is a part of the mixture control assembly. It consists of a valve and the necessary channels drilled in the bodies. The valve is opened during the last few degrees of mixture control lever movement toward the full lean position. With valve open and the throttle closed, the manifold suction existing above the throttle valve is transposed directly on top of the fuel chamber by means of a drilled passage in the body, and the fuel flow through the idle system is stopped, thereby causing the engine to cease firing immediately.

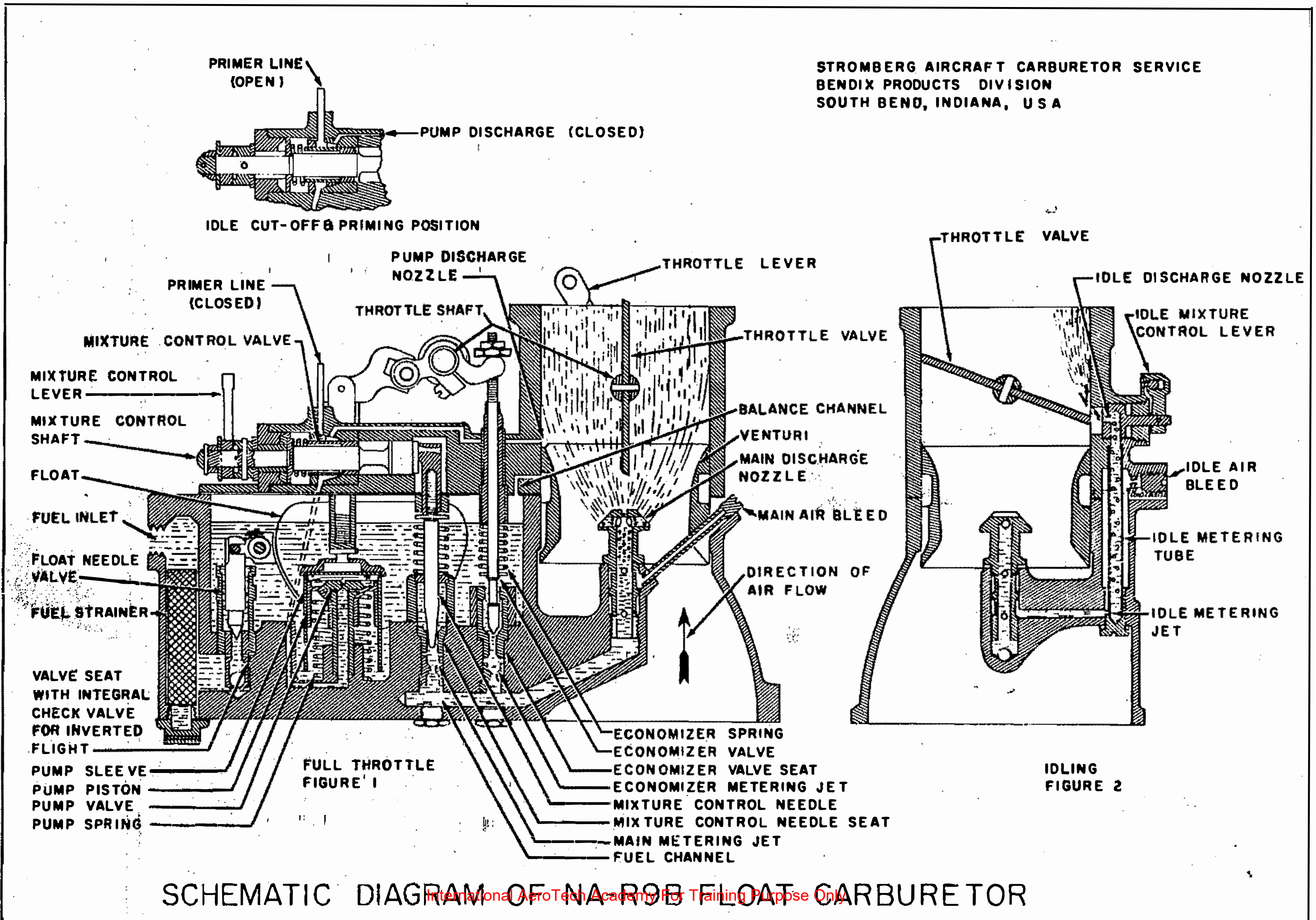
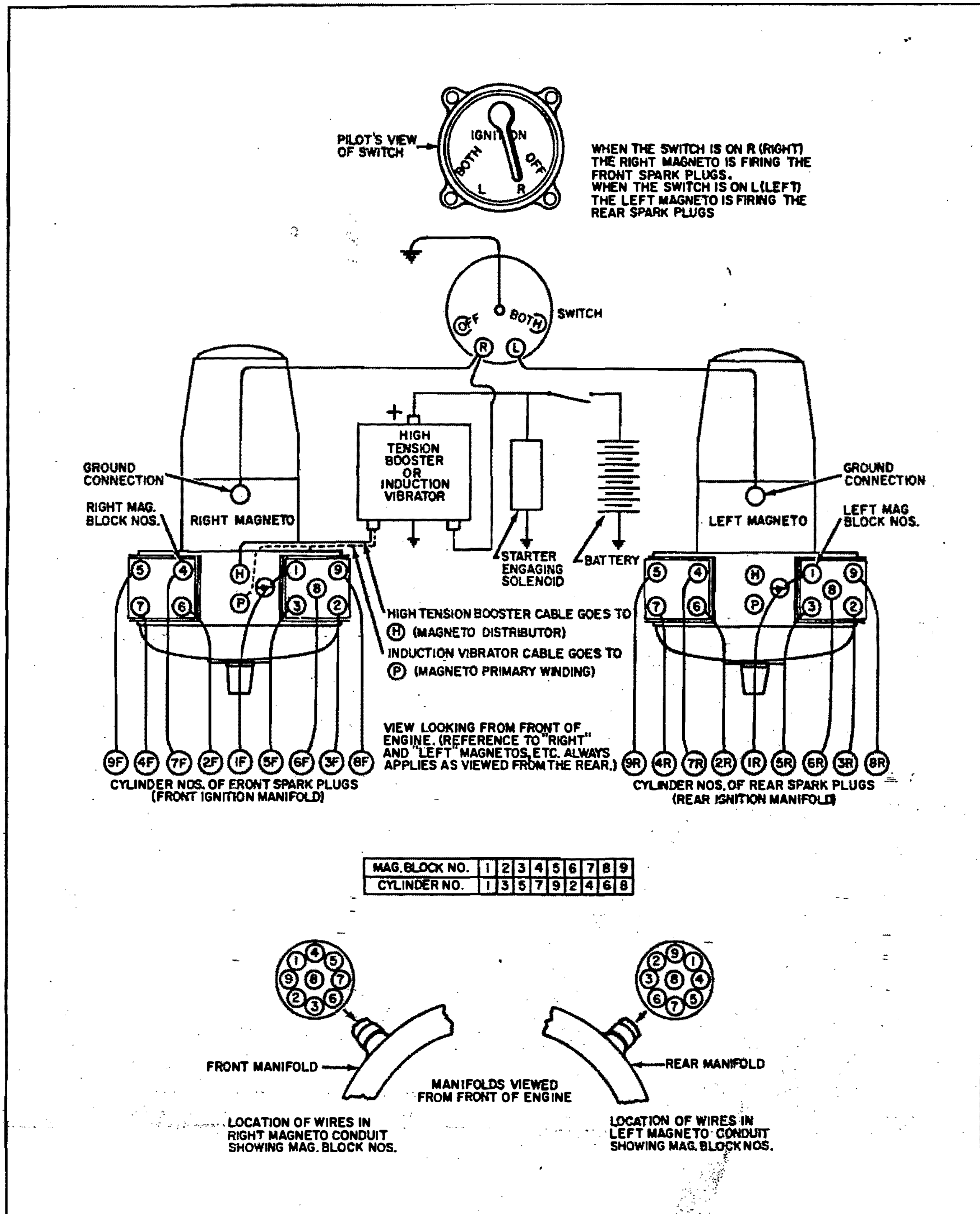


Figure 2—23. Schematic Diagram, Showing F/A Flow



MAG. BLOCK NO.	1	2	3	4	5	6	7	8	9
CYLINDER NO.	1	3	5	7	9	2	4	6	8

Figure 2—24. Schematic Diagram of Ignition System

2—42R. SUMMARY.

2—42S. The specifications or settings in these carburetors are the result of a great deal of test work conducted by the engine and carburetor manufacturers in the laboratory and in flight, and should not be changed unless specific instructions are issued by the manufacturer. In a case where unusual operating conditions necessitate a change, the carburetor manufacturer will issue any necessary instructions upon application.

2—42T. IGNITION.

2—42U. IGNITION. Ignition *[Figure 2—24]* is furnished by a synchronized, dual, high tension, Scintilla or Bosch Magneto ignition system *[Figure 2—25]*. An installation includes two magnetos, two distributor assemblies, a manifold assembly *[Figure 2—26]*, and two sparkplugs in each cylinder. The magnetos are mounted at the rear of the engine. The right magneto fires the front sparkplug in each cylinder; the left magneto fi the rear sparkplug, and both plugs are fired simultan ously. However, since the two ignition systems are ele trically independent, satisfactory operation will still obtainable with reduced power should one system fa

2—42V. Dual ignition permits greater horsepower ou put with less tendency of the fuel to detonate. Hig tension current is generated and timed by the magne which is independent of any other accessory, therel assuring uninterrupted performance of one of the mo vital parts of the aircraft engine. Radiation of uncoı trolled high frequency current emanating from the ign tion system is minimized by encasing the entire ignitic system with a metallic covering known as radio shieldin;

2—42W. The magneto employs four magnetic poles. Th poles of the rotating magneto are arranged in alterna polarity so that a change in the flux direction occu

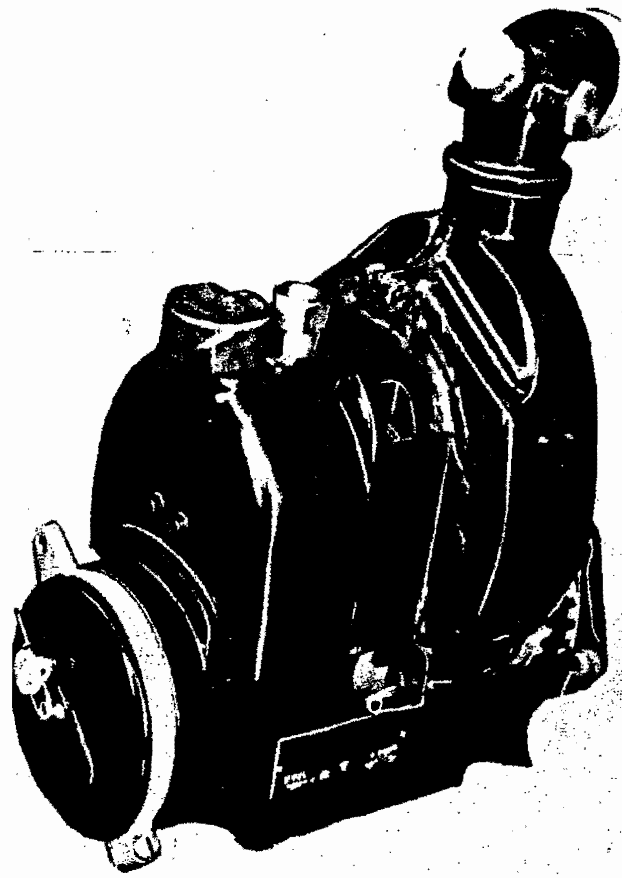


Figure 2—25. Scintilla Magneto

with rotation. The number of flux reversals during one complete revolution of the assembly is equal to the number of poles on the magnet. In this arrangement, the coil assembly remains stationary. The flux density depends on the area of the magnetic pole engaged by the pole shoe. The electromotive force induced across the windings is proportional to the rate of charge of the flux. The voltage that the magneto is allowed to develop is determined by the sparkplug gap dimension and the density of the charge in the cylinder at the time of discharge.

2—43. STARTER. A SAE standard aircraft starter mounting flange is provided on the rear section for mounting a starter *(Figure 2—19)*.

2—44. LUBRICATION *[Figures 2—27 and 2—28]*.

2—45. GENERAL. Oil is circulated through the engine by the three section gear pump which consists of one pressure and two scavenge sections *[Figure 2—29]*. The pump is located in the right side of the rear case. Oil from the tank enters the oil pump through a port in the pump cover. The oil is then directed to the pressure stage of the pump and from there flows under pressure to the

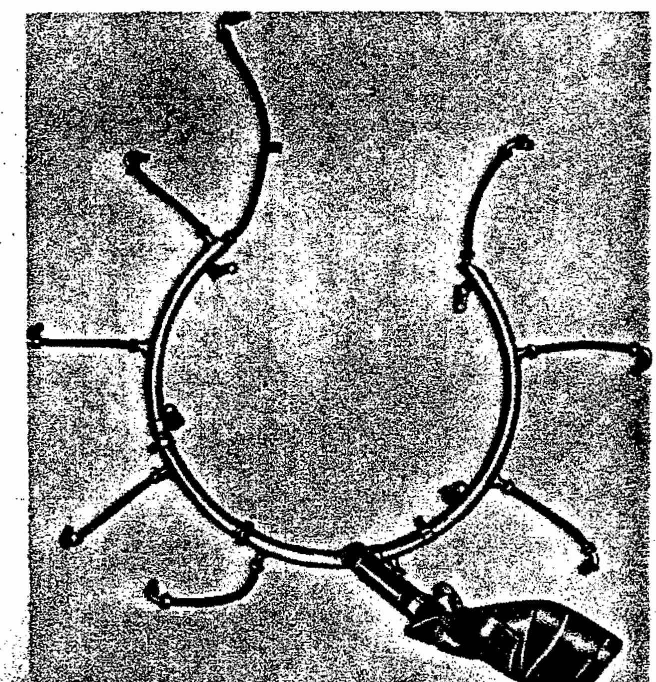


Figure 2—26. Rear Ignition Manifold

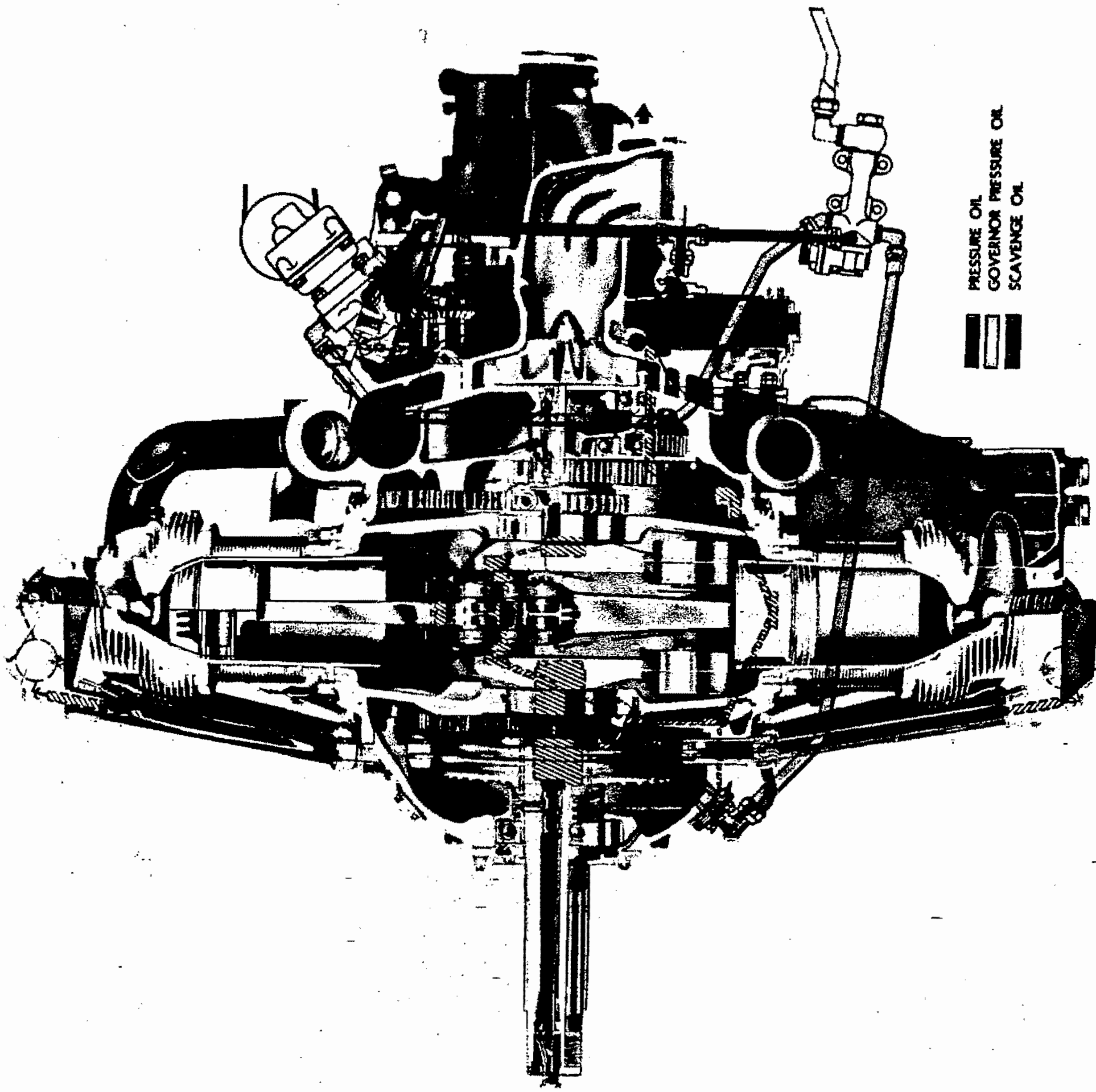


Figure 2–27. Lubrication Chart

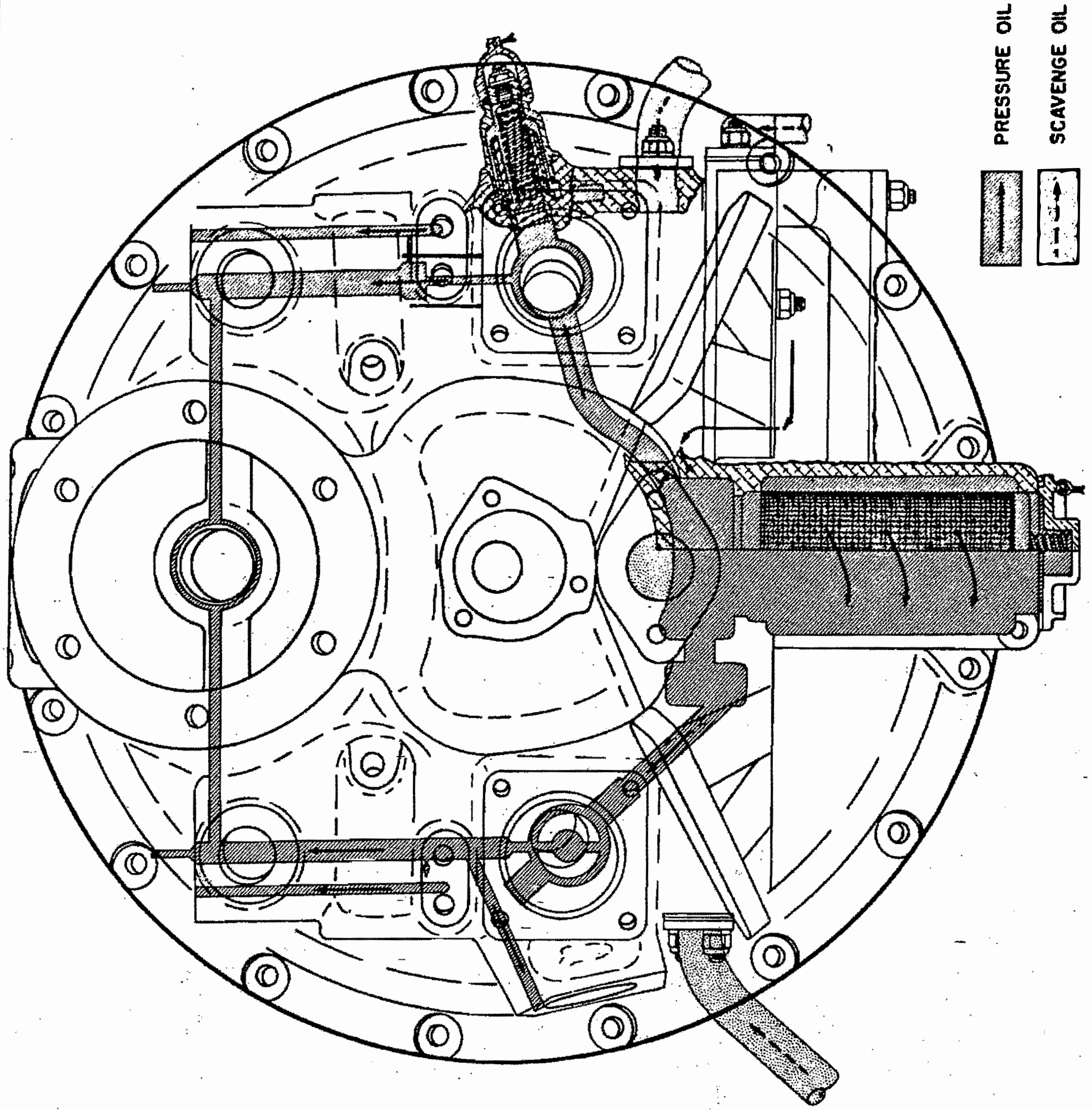


Figure 2—28. Rear Section Lubrication Chart

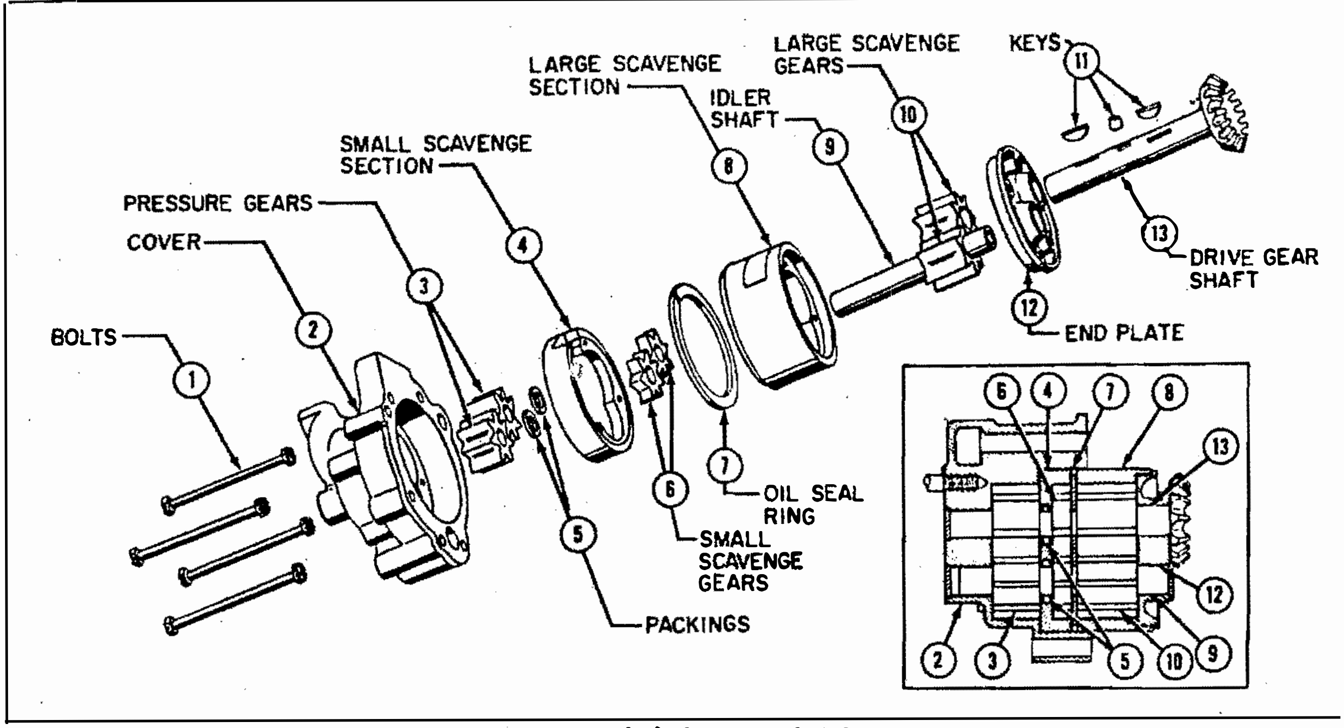


Figure 2—29. Exploded View of Oil Pump

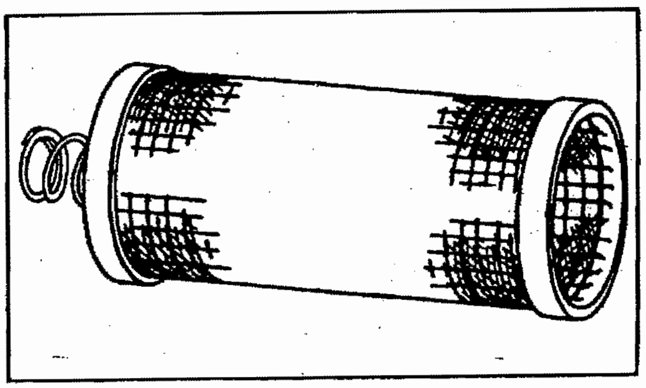


Figure 2—30. Oil Strainer

oil strainer chamber, via a cored passage in the rear case. After entering the oil strainer chamber, the oil passes through the strainer assembly *[Figure 2—30]*, and then through the spring loaded check valve. When the engine is not running the check valve prevents oil from seeping into or out of the engine. When the oil emerges from the check valve in the oil strainer assembly, it is diverted into two main branches. The flow of oil through each branch is described separately under paragraphs 2—47 through 2—54.

2—46. FIRST BRANCH.

2—47. The oil is directed through a passage to an annulus around the right magneto drive gear shaft rear bushing. Part of the oil from this annulus is carried by drilled passages to the right accessory drive gear bushings. Here the oil enters the hollow accessory drive gear shaft and flows upward to the starter shaft bushing. Part of the oil from this annulus flows upward through a drilled passage to lubricate the accessory and another part enters the magneto drive gear shaft and flows forward to lubricate the front bushing.

2—48. Another passage carries the oil from the annulus encircling the right magneto drive gear shaft rear bushing to the oil pressure relief valve, which regulates the engine oil pressure. Bypassed oil is returned to the inlet side of the oil pump pressure section.

2—49. SECOND BRANCH.

2—50. The oil in this branch is directed to the left side of the rear case where the oil flow divides. Part of the oil enters the annulus which encircles the left magneto drive gear shaft rear bushing. Drilled passages from this annulus carry oil to the left accessory drive gear bushing. Here the oil enters the hollow accessory drive gear shaft and flows upward to the starter shaft bushing. Other drilled passages and tubes carry the oil to the vacuum pump, tachometer, and starter gears. Oil from the annulus around the left magneto drive gear shaft rear bushing flows upward through a drilled passage to lubricate the accessory; oil also enters the shaft and flows forward to an annulus around the front bushing where it is directed by a drilled passage to the front of the supercharger case. Here the oil provides lubrication for the impeller shaftbearings.

2—51. Oil for the crankcase and front section is carried from the left side of the rear case through the rear and supercharger case by a tube. The supercharger case oil pressure tube bracket supports a tube assembly which transfers the oil to the crankcase and also provides spray lubrication for the floating gear and impeller interme-

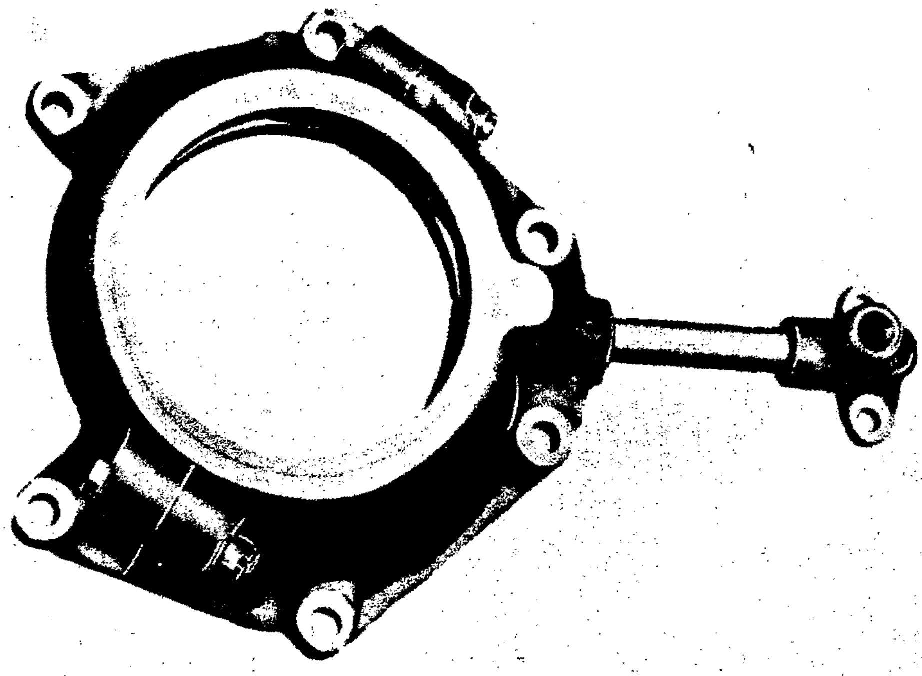


Figure 2–31. Cam Oil Feed Bracket

diate drive gear. The oil passes from the pressure tube bracket through a series of tubes and drilled passages in the crankcase to the cam oil feed bracket *[Figure 2–31]* on the front face of the crankcase.

2–52. At the cam oil feed bracket the oil is directed into two channels. In the first channel the oil flows to the front case where it enters the rocker oil manifold. Hollow screws transfer the oil to the tappets. From there oil is forced through the pushrods to the rockers. In the second channel the oil is forced through the cam oil feed bracket into the crankshaft. Holes in the crankpin, the masterod bearing, and masterod provide for the splash lubrication of the pistonpins, pistonpin bushings, and flyweights.

2–53. SCAVENGE OIL.

2–54. The surplus oil in the engine proper drains into the main sump from where it is pumped back through the scavenge pump. Oil from the rockerbox drains through the pushrod cover tubes to the front case, or through a system of intercylinder drains to an additional compartment in the sump from where it is returned to the oil tank. The rear case oil drains through a tube into the supercharger case, then into the sump.

SECTION III

SPECIFICATIONS

	ALL MODELS
GENERAL	
Type	Single Row, Radial, Air-Cooled
Number of Cylinders	9
Bore	5.1875 inches
Stroke	5.1875 inches
Piston Displacement	985 cubic inches
Compression Ratio	6:1
Impeller Ratio	10:1
Impeller Diameter	6.87 inches
Crankshaft Rotation	Clockwise
Crankshaft Spline Size	SAE No. 30
Diameter of Mounting Bolt Circle	23.375 inches
Number of Mounting Bolts	9
Overall Diameter of Engine	46.25 inches
Overall Length of Engine	43.05 inches
Approximate Center of Gravity:	
Forward of Mounting Boss Rear Face	6.88 inches
Distance Below Crankshaft Centerline	.38 inch
VALVES AND TIMING	
Intake Opens	26 degrees Before Top Center
Intake Closes	76 degrees After Bottom Center
Exhaust Opens	71 degrees Before Bottom Center

	ALL MODELS
Exhaust Closes	31 degrees After Top Center.
Intake Remains Open	282 degrees
Exhaust Remains Open	282 degrees
Cold Valve Adjusting Clearance	.010 inch
Valve Timing Check Clearance	.060 inch
Valve Lift:	
Exhaust	.4687 inch
Inlet	.5625 inch
IGNITION SYSTEM	
Magneto Type	SB9RU-3 or SB9RN-3
Rotation of Magneto Drive	Counterclockwise
Magneto Speed Ratio to Crankshaft	1.125:1
Magneto Blast Tube Connection	.750-14 NPT
Spark Plug Gap	.011 inch-.014 inch
Spark Plug Types	706SR RC-26S RB-485S SH-2K
Spark Advance	25 degrees Before Top Center
FUEL SYSTEM	
Fuel Required In Flight	Specification No. MIL-F-5572, Grade 91/96
Fuel Inlet Connection	.375-18 NPT
Fuel Pressure Connection	.125-27 NPT
Manifold Pressure Gage Connection	.125-27 NPT

LUBRICATION SYSTEM	
Grade Of Oil Required	Specification No. MIL-L-6082, Grade 1100 or 1120
Oil Tank Vent Connection	.750-14 NPT
Oil Pressure Gage Connection	.125-27 NPT
Oil Outlet Thermo. Connection	.625-18 NF-3
Oil Inlet Thermo. Connection	.625-18 NF-3
Breather Connection	.750-Hose
Accessory Oil Return to Engine	.375-18 NPT (Left Side of Sump)
Starter Drive:	
Pad Stud Centers	5 inch diameter Bolt Circle
Speed to Crankshaft	1.00:1

	ALL MODELS
ACCESSORY DRIVES	
Rotation	Counterclockwise
Generator Drive:	
Type of Drive	6 internal Rectangular Splines
Pad Stud Centers	5 inch diameter Bolt Circle (Square Pad)
Rotation	Clockwise
Fuel Pump Drive:	
Type of Drive	11 Internal Involute Splines
Pad Stud Centers	2 x 2 inch Square Pad
Vertical Auxiliary Drives:	
Type of Drive	16 External Rectangular Splines
Pad Stud Centers	1.875 x 1.875 inch Square Pad
Speed to Crankshaft	1.00:1
Rotation	Counterclockwise
Vacuum Pump Drive:	
Type of Drive	12 Internal Involute Splines
Pad Stud Centers	1.875 x 1.875 inch Square Pad
Speed to Crankshaft	1.50:1
Rotation	Clockwise
Speed to Crankshaft	1.00:1
Rotation	Counterclockwise
Tachometer Drives:	
Type of Drive	.875-18 NS-3 Coupling
Speed to Crankshaft	.50:1
Rotation	Clockwise (Right Side) Counterclockwise (Left Side)

DISTINGUISHING FEATURES

MODEL R-985	-AN-1	-AN-3	-AN-39	-AN-39A
Average Dry Weight	674 lbs	682 lbs	674 lbs	682 lbs
Carburetor	NA-R9B	NA-R9B	NA-R9B	NA-R9B
(CARB) Setting	18	18	18	18
Starter Jaw No. of Teeth	3	3	3	3
Generator Drive Ratio	1.5:1	1.5:1	2:1	2:1

SECTION IV

PREPARATION FOR STORAGE OR SERVICE

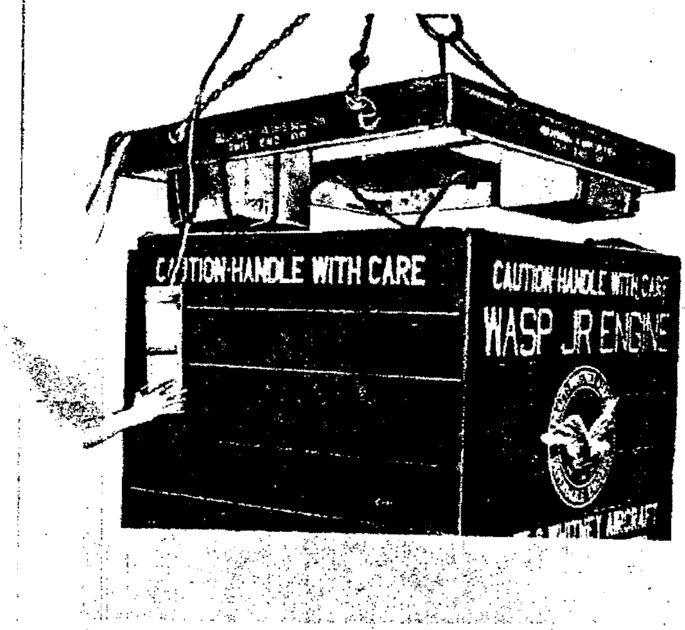


Figure 4—1. Removing Packing Case Cover

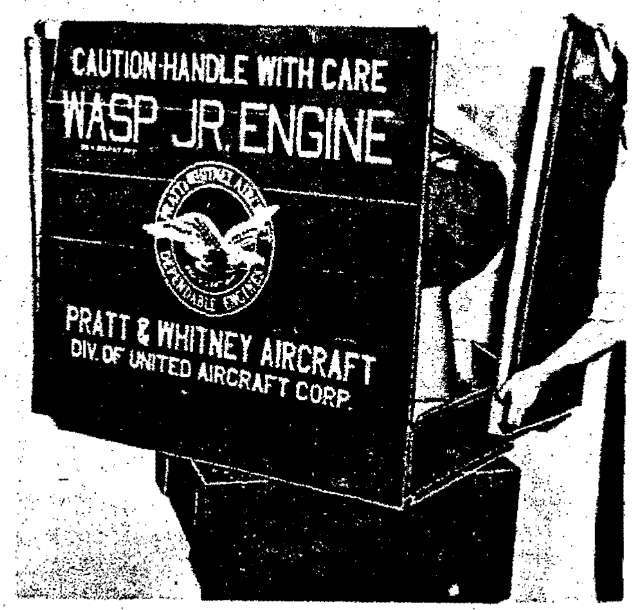


Figure 4—2. Lifting 4 Sides From Base

4—1. UNPACKING THE ENGINE.

4—2. GENERAL.

a. Engines received at operating activities have been prepared for storage in accordance with Specification MIL-E-6058.

b. When unpacking an engine, do not turn the propeller shaft or drain the corrosion preventive mixture from the engine. Do not remove the carburetor mounting pad cover, exhaust port covers, or any dehydrating plugs.

c. Handle pliofilm envelopes at temperatures of 20°C (68°F) or higher. Lower temperatures tend to stiffen the envelope material, thereby creating difficulties in handling and making the envelopes more vulnerable to rupture.

d. The rings on the cover of the case are used only for lifting the cover.

4—3. REMOVING THE ENGINE IN A VERTICAL POSITION.

a. Remove the metal straps from the case.

b. Attach a sling to the two rings on each side of the cover, and lift the cover from the case (*Figure 4—1*) carefully in order to prevent damage to the carburetor, which is in a carton fastened inside the packing case cover. Lift the front sides out of the base (*Figure 4—2*).

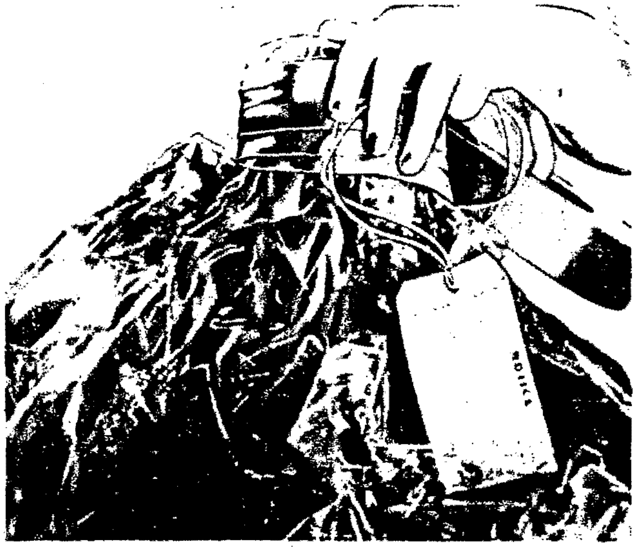


Figure 4–3. Remove Tape

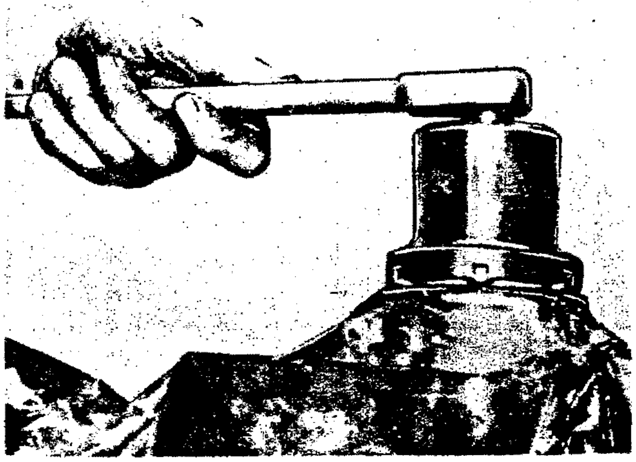


Figure 4–4. Unscrew Protector Cap

c. Remove the tape *[Figure 4–3]* which gathers the top of the engine protective envelope around the propeller shaft and open the envelope by cutting off the sealed portion. Cut off as little envelope material as possible so that the envelope can be reused. Unscrew the protector cap and spanner nut *[Figure 4–4]*; then remove the protective envelope and spacer from the propeller shaft *[Figure 4–5]*.

d. Remove the nuts and lockwashers which secure the engine to the mounting plate. Install PWA-520 Lifting Eye on the propeller shaft, and lift the engine from the case by means of a chain hoist (two tons minimum) *[Figure 4–6]*. Roll the protective envelope down from the engine, wipe it clean, and store it for further use.

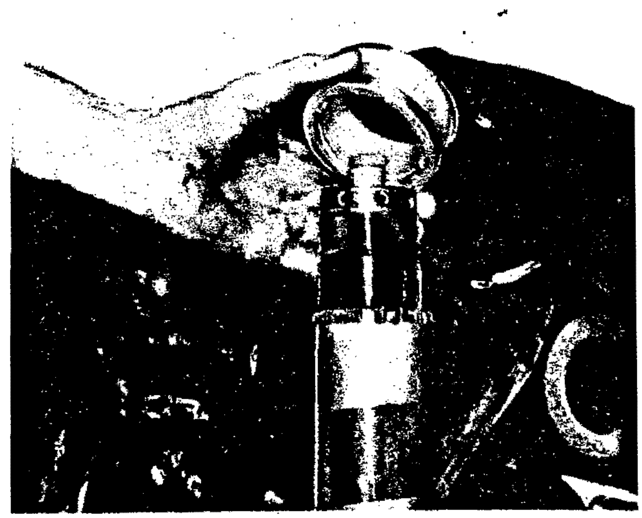


Figure 4–5. Remove Spacer From Prop Shaft

Figure 4–6. Lift Engine With Chain Hoist

e. Lower the engine into R85-S-62000 Engine Stand equipped with R85-P-31300 Mounting Plate and secure it with the bolts, lockwashers, and nuts *[Figure 4–7]*. Remove the bags of dehydrating agent which are secured to the cylinders and remove the humidity indicator.

f. Crank the bed of the engine stand until the engine is in the flight position. Attach PWA-37 Lifting Sling to a chain hoist and attach the hooks on the sling to the

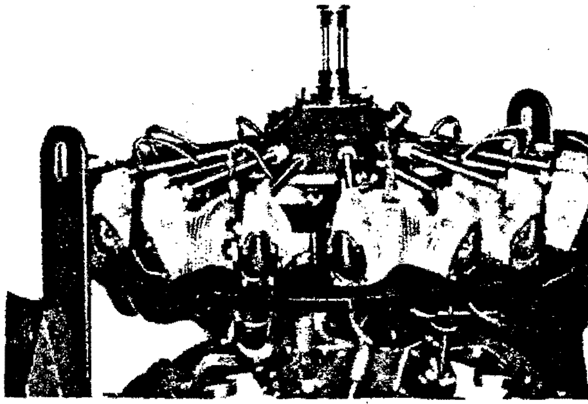


Figure 4—7. Engine in Stand

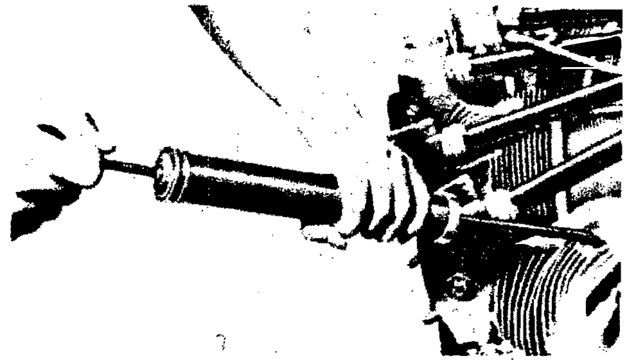


Figure 4—8. Hand Pump — Removing Oil From Cylinder

two lifting eyes on the engine. Draw up on the hoist enough to relieve the stand of the engine's weight. Remove the nuts, lockwashers, and bolts which secure the engine and withdraw the engine from the stand.

4—4. REMOVING THE ENGINE IN A HORIZONTAL POSITION.

a. The procedure for removing the engine from the packing case in a horizontal position is the same as that described for removing it in a vertical position up to the point of opening the engine protective envelope.

b. Install PWA-520 Lifting Eye on the propeller shaft. Lift the engine until the base of the packing case is about 2 feet off the floor, then secure a block and tackle or a long piece of heavy rope around the base, and pull the base to one side so that an edge of the base will come to rest on the floor and act as a fulcrum while the nose is being lowered into the flight position. Maintain enough tension on the hoist to prevent the engine from nosing over too far.

c. Roll back the protective envelope as far as the supercharger section; then attach PWA-37 Lifting Sling to a second chain hoist (two tons minimum), and attach the hooks on the sling to the two lifting eyes on the engine. Draw up on this hoist enough to relieve the base of the engine's weight; then remove the nuts and lockwashers which secure the engine to the mounting plate and withdraw the engine from the case. Remove the protective envelope from the engine, wipe it clean, and store it for further use.

4—5. PREPARING THE ENGINE FOR INSTALLATION.

4—6. GENERAL.

4—7. The instructions for engine build up treat only major components. In case any part of the following instructions are in conflict with or superseded by the airframe manufacturer's publications, the instructions contained in the latter are applicable. For additional details and specific requirements refer to the installation drawings for the particular aircraft involved; these drawings are provided by the aircraft manufacturer.

4—8. The vertical auxiliary accessory drive pads have drilled .188 in. diameter holes for pressure oil if the pads are of the low type. High pads have no provisions for pressure oil. An oil supply is available through the center of the propeller shaft by removing a plug in the end of the shaft. The vacuum pump pad is provided with a .1405 in. drilled hole for pressure oil.

4—9. When a propeller governor is used on the R-985 engine, oil under pressure should be piped from the main oil strainer chamber to the governor. The governor return oil should be drained to the rear section by an external pipe connected to the point shown on the Installation Drawing.

4—10. For lubrication requirements of various accessories, refer to the applicable accessory manufacturer's instructions.

4—11. For torque recommendations refer to "Torque Recommendations" paragraph 7—110.

4—12. MIXTURE DRAINAGE. The following instructions should be carried out just prior to the initial ground run of the engine and in no case prior to 1 week before engine operation. If desired, the engine may be installed in an engine build-up stand for depreservation, installation of accessories, or build-up of a complete power unit.

4—13. ENGINE OPENINGS. Remove the moisture-proof coverings, containers of dehydrating agent, and dehydrating plugs from the breathers and other engine openings.

CAUTION

Be sure to remove yellow shipping plugs, caps, and covers and replace with appropriate flight fitting when engine is installed in an airplane.

4—14. CORROSION PREVENTIVE MIXTURE. Remove the starter pad cover plate, the oil outlet protector cover and all drain plugs. Remove the sparkplug leads from the dehydrator plugs; then remove the dehydrator plugs from the cylinders and, with the engine in a vertical position, allow the corrosion preventive mixture to drain from the engine. Turn the engine over by hand, using PWA-112 Turning Bar, at least six complete revolutions in the normal direction of rotation to facilitate draining. Using a small inspection light, inspect the insides of the cylinders through the sparkplug holes to

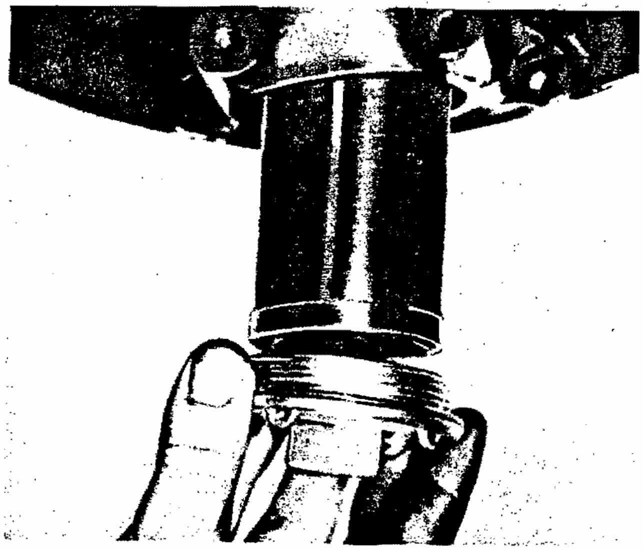


Figure 4—9. Remove Oil Strainer

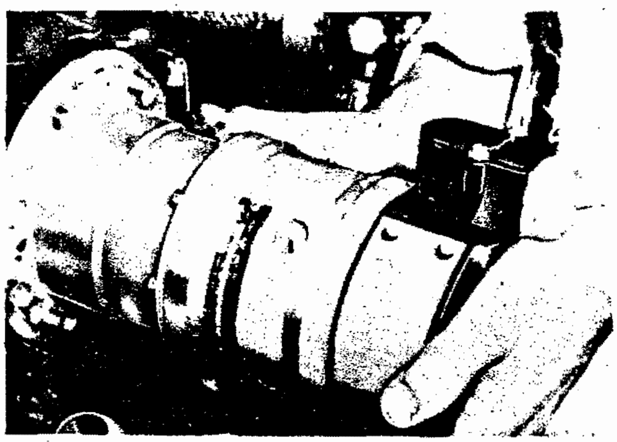


Figure 4—10. Mount Starter

make sure that the oil or mixture has not accumulated in them. If an appreciable quantity is present, remove it with a hand pump (*Figure 4—8*). To insure removal of mixture from intake pipes, process engine as follows:

a. If the engine is depreserved in a horizontal position, remove the two bottom-most pipes and drain all corrosion preventive mixture from them. If excess mixture is found in the pipes, remove and examine the adjacent intake pipes on each side of the engine, continuing toward the top cylinder until no excess mixture is found.

b. When removing intake pipes, remove packing nut at supercharger first, and then nuts and bolt at cylinder. Perform these operations in reverse order when installing intake pipes.

4—15. OIL STRAINER. Remove oil strainer from oil strainer chamber (*Figure 4—9*). Clean the strainer thoroughly. Center a new oil chamber cover gasket on cover, using a small amount of lubricating grease (Specification MIL-L-3545) on both sides of gasket. The gasket is to be installed with the smooth side toward the shoulder of the cover (crimped or asbestos-exposed side toward engine). This procedure keeps the gasket from turning and wearing a pattern into its sealing part while the plug

Figure 4—11. Align Mounting Bolt Holes

is being tightened. Install gasket and cover. Tighten cover with PWA-228 Wrench. Lockwire the cover.

4—16. WASHING THE ENGINE. If necessary, wash the exterior of the engine with kerosene (Specification VV-K-211) or dry cleaning solvent (Specification P-S-661), being careful to keep the cleaning fluid away from the ignition cable assembly. Dry the engine with compressed air.

WARNING

Avoid prolonged breathing of solvent and kerosene vapors and prolonged or repeated contact with skin. Observe fire precautions. Do not direct compressed air against skin.

4—17. STARTER.

4—18. Remove the shipping cover and gasket from the engine mounting pad.

4—19. Check the jaw of a new starter with engine meshing jaw for size, number and slant of teeth. If sizes differ, the starter is the wrong model for the engine. Check starter to make sure it rotates in the proper direction.

4—20. Wipe mounting pad and starter mounting flange clean, and place a clean, dry gasket on studs; then mount starter (*Figure 4—10*) and secure with washers and nuts.

Note

Remove paint, dirt, grease, etc., under three nuts on the flange to assure proper grounding.

4—21. ENGINE MOUNT.

4—22. Two types of engine mounting may be used. In one case, through-bolts are used to attach mount lugs to engine at the nine points of attachment on the ring.

4—23. The second type of mounting uses vibration isolators. The vibration isolators are not engine parts and, therefore, are not covered in these instructions.

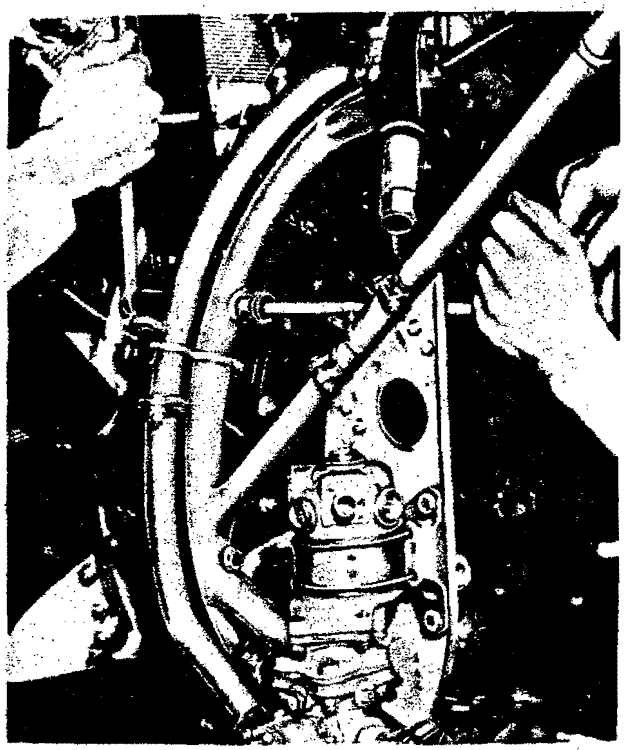


Figure 4-12. Tighten Mount Nuts and Bolts

4-24. Remove the engine from the engine stand by means of a suitable hoist (two tons minimum) and sling. For build up, the engine may be supported by the hoist and sling or installed in a transportation stand if one is available. Align the mounting ring bolt holes with the mating holes in the mounting bosses [*Figure 4-11*]. Install the bolts and nuts; then tighten [*Figure 4-12*] to the recommended torque.

4-25. VACUUM PUMP.

4-26. Remove the cover plate and the gasket from the engine pump pad, and wipe the pad clean. Check the oil holes in the pad to insure free oil passage.

4-27. Remove the shipping plugs from the two ports, and test the pump manually for freedom of operation.

4-28. Pour a small quantity of engine lubricating oil (Specification MIL-L-6082) into the pump ports and rotate drive coupling assembly several times by hand to insure a good distribution of lubricating oil on walls, vanes, and bearings. The pump rotor should turn freely. If there is evidence of binding, forward pump to overhaul.

4-29. Coat the drive spline of the pump with lubricating grease (Specification MIL-L-3545).

4-30. Place the mounting gasket that is supplied with the pump on the engine mounting pad studs making sure that the oil holes in the gasket line up with the oil holes in the engine mounting pad.

4-31. Carefully mate and engage the pump drive with the engine drive member, then secure and lockwire [*Figure 4-13*].

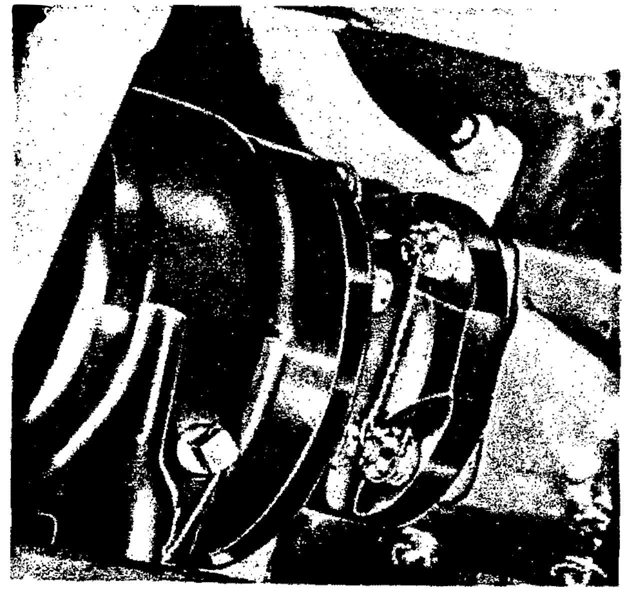


Figure 4-13. Pump Secured and Lockwired

Figure 4-14. Place Generator on Studs

Note

The pump may be rotated to the desired position to facilitate completion of the air tubing connections to the pump ports.

4-32. GENERATOR.

4-33. Remove the cover plate and gasket from the engine mounting pad, wipe the mounting pad clean and reassemble the gasket on the pad.

4-34. Remove any paint, grease, and dirt from the generator flange to provide electrical bonding contact for the generator mounting nuts.

4-35. Coat the drive spline of the generator with lubricating grease (Specification MIL-L-3445).

4-36. Determine the best mounting position for alignment and attachment of the electrical leads. Place the generator on the mounting studs [*Figure 4-14*] and

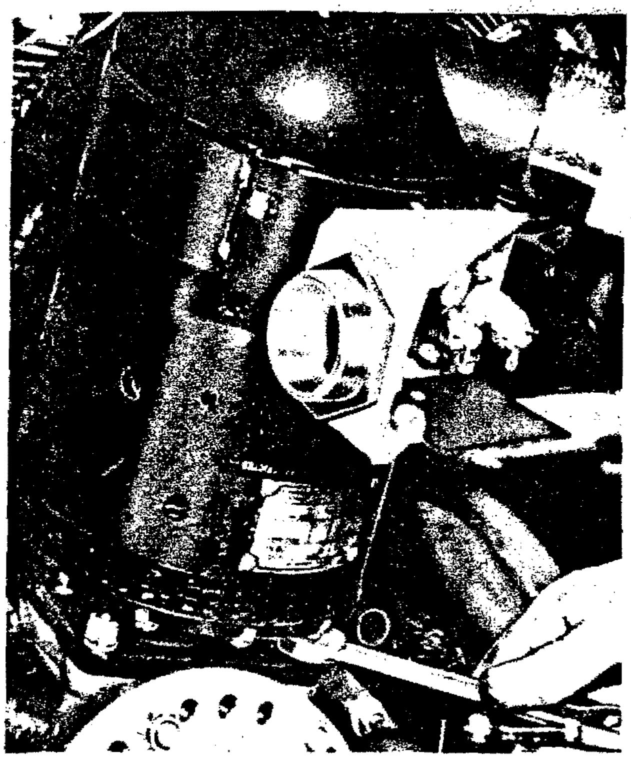


Figure 4—15. Tighten Generator Nuts

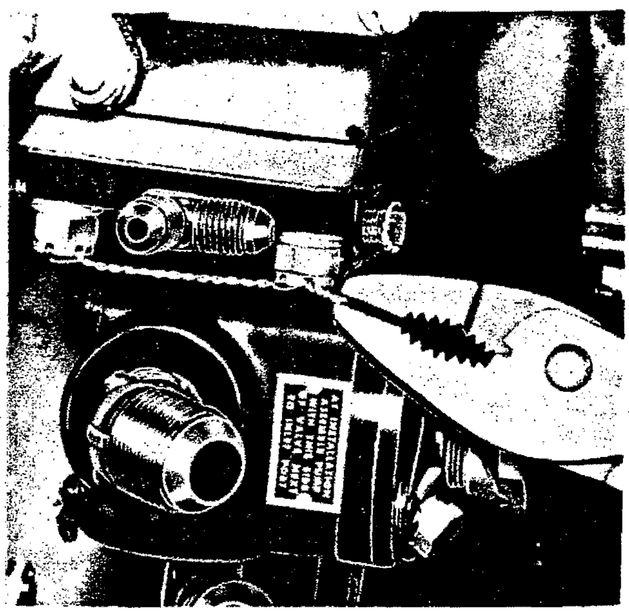


Figure 4—16. Fuel Pump Lockwired

screw on the mounting stud nuts. Tighten the nuts securely *[Figure 4—15]*.

4—37. Loosen the screws holding the blast tube adapter, swing the adapter to the required angle.

4—38. For additional details, refer to the installation drawings provided by the aircraft manufacturer.

4—39. EXHAUST STACKS. Place the exhaust stack and gasket (smooth side against the cylinder) on the mounting studs; then secure with nuts and palnuts.

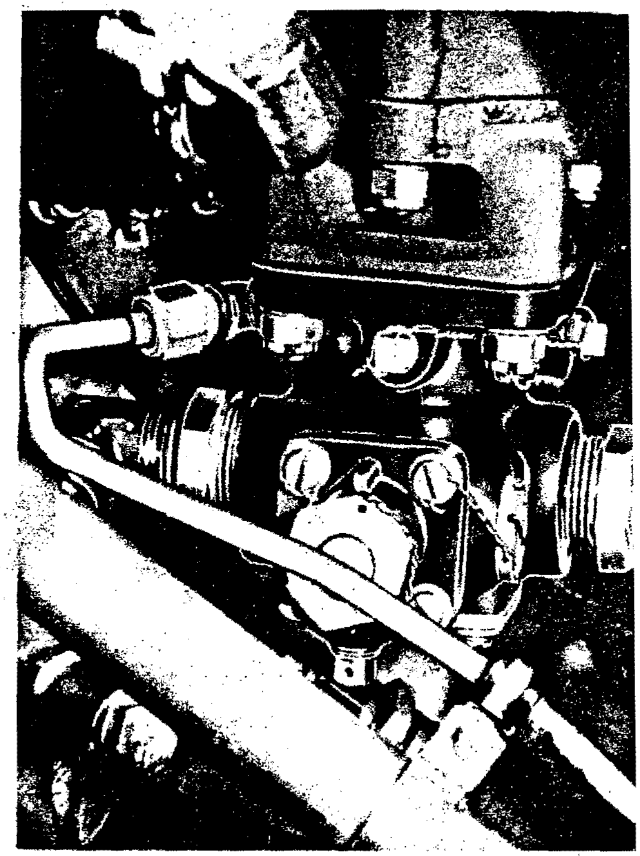


Figure 4—17. Drive Shaft Seal Drain Line

4—40. FUEL PUMP.

4—41. Check the part and type numbers stamped on the pump against the specific requirements. Prepare the pump for installation by removing the shipping block from the flange, the Protek plug from the inlet port and the plain plug from the outlet port. Oil flushed pumps should be cleaned by flushing with clean dry cleaning solvent (Specification P-S-661). Turn the drive shaft with fingers to check freedom of pump operation.

4—42. Make certain the mounting surfaces of the pump and engine are clean. Place a new gasket on the studs and mount the pump. Secure with washers and nuts; then lockwire *[Figure 4—16]*. Connect the proper fuel lines, using an approved anti-seize thread compound (Specification MIL-T-5544) to the inlet and outlet ports. Remove the vent plug from the valve housing cover and install the balance line which vents this outlet with the carburetor top deck. Connect the drive shaft seal drain line to the drain hole *[Figure 4—17]*.

4—43. During ground checks of the engine it may be necessary to adjust the fuel pressure. To do this, loosen the lock nut and turn the adjusting screw clockwise to increase the fuel pressure, or counterclockwise to decrease the pressure. When the lock nut is tightened it may change the discharge pressure slightly, so it is advisable to take this condition into account when the adjustment is being made. Make certain the lock nut is tightened and lockwired after the adjustment has been made.

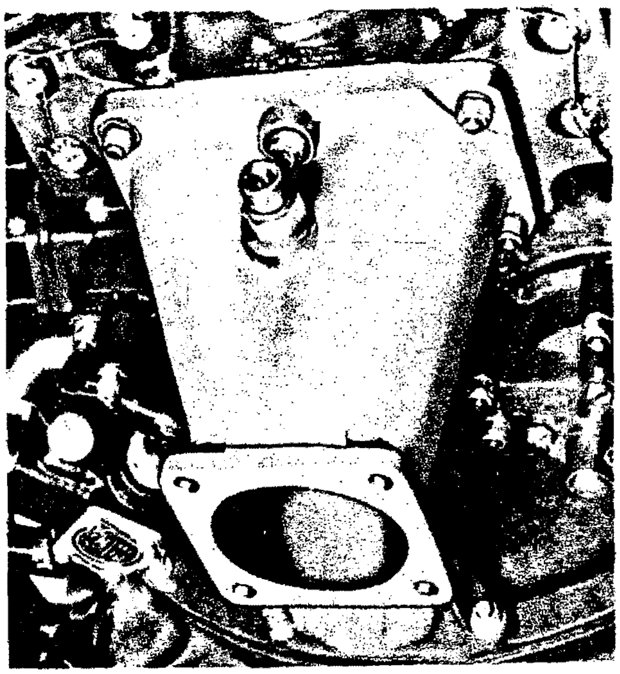


Figure 4–18. Install Carburetor – Adapter

4–44. CARBURETOR.

4–45. Flush the carburetor through the fuel inlet opening with clean unleaded gasoline (Specification VV-G-109) and allow the gasoline to drain. Repeat this operation until all the storage oil has been completely washed out.

4–46. The NA-R9B carburetor is mounted on the engine with the float chamber at the side and with the fuel inlet to the rear. The fuel inlet is a 3/8 inch pipe tap connection located at the top of the strainer boss. A 1/8 inch pipe tap primer connection is located on top of the mixture control boss. The mixture control and throttle levers may be adjusted radially to any position. The 70 degree throttle lever travel requires a control rod movement of 2-9/32 inches.

4–47. Detach the carburetor mounting pad cover from the engine. Install the carburetor adapter on the carburetor mounting pad, no gasket is required, and tighten the six nuts [*Figure 4–18*].

4–48. Install the carburetor (no gasket) and tighten the attaching nuts [*Figure 4–19*].

4–49. AIRSCOOP ADAPTER. Install the carburetor air intake screen assembly using a gasket on either side of screen mounting flange. Place the airscoop adapter over the screen and secure with washers and screws; then lockwire.

4–50. MAGNETO VIBRATOR AND GROUND LEADS. Lightly coat the magneto ground spring connectors with insulating compound (Specification MIL-L-8660). Insert a connector into the ground terminal of each magneto. Screw the connector cap onto the ground terminal threads and secure with the clip.

WARNING

The insulating compound contains minutely ground silica and mica which may act as irritants to the eyes and skin. When compound is handled frequently, it is suggested that gloves be worn.

4–51. PROPELLER GOVERNOR [*Figure 4–20 and Figure 4–21*]. When a propeller governor is required, either the left or right vertical auxiliary drive may be used to mount a 35 degree angular mounted constant speed control. Oil under pressure is piped from the main oil strainer chamber to the governor. Return oil from the governor is drained into the engine rear section through the oil tank vent connection. Propeller control oil is piped from the governor to the engine front case through an external tube. Installations calling for the use of a "Hydromatic" propeller will use a feathering pump and a transfer valve and cutout switch. Complete instructions for the installation of a propeller governor are given in the service manual issued by the manufacturer of the governor.

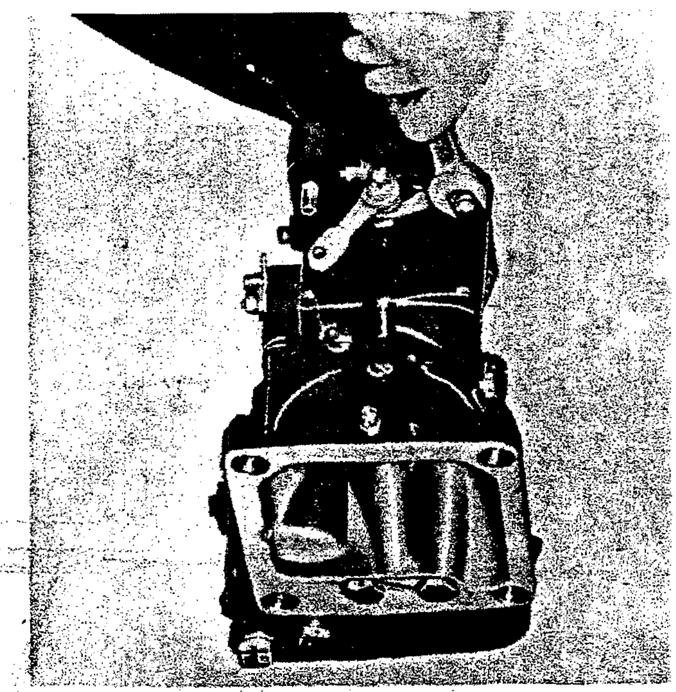


Figure 4–19. Install Carburetor

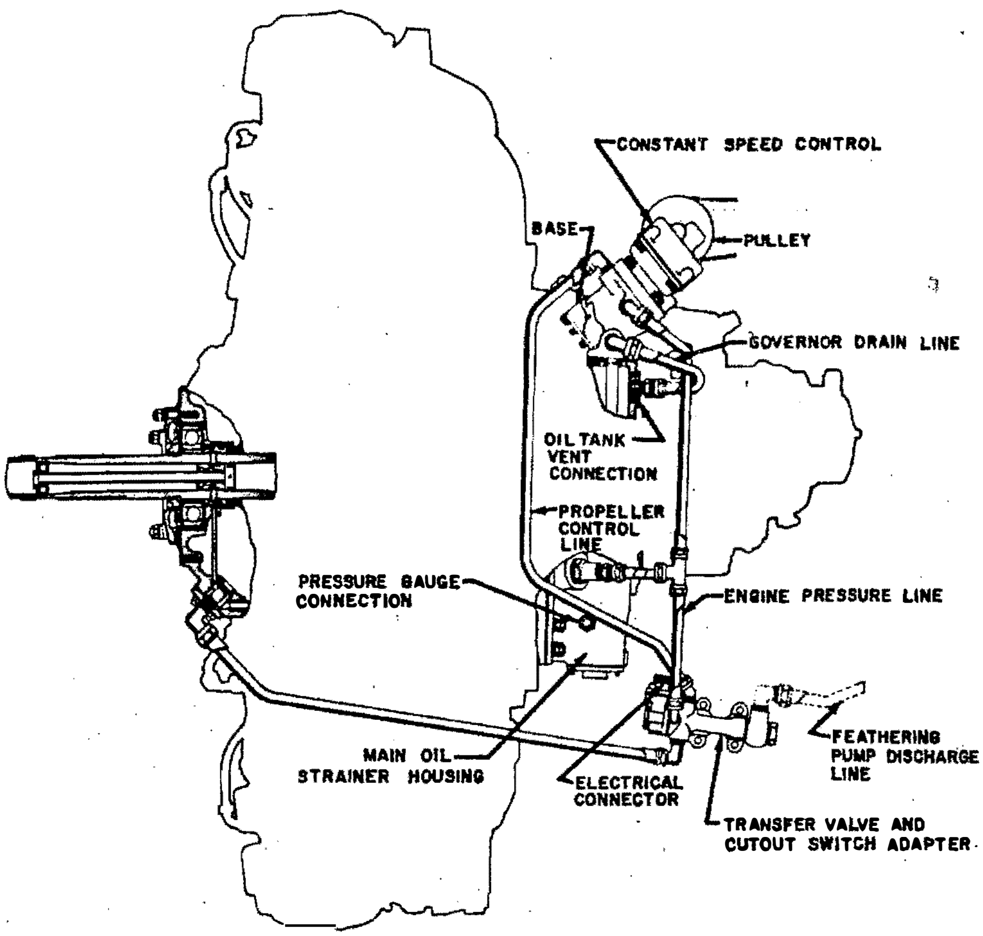


Figure 4–20. Schematic Governor – Hydromatic Installation

4–52. DEPRESERVATION VALVES, SPARKPLUGS, AND SPARKPLUG CONNECTORS.

a. Install a Depreservation Valve [Figure 4–22] in the lower most sparkplug hole of the following cylinders: 4-5-6 and 7. Refer to "Initial Ground Run," paragraph 4–60, for engine operating instructions, using depreservation valves. Depreservation Valves are useful in removing fluid from the combustion chamber and intake pipe of the cylinder in which they are installed. The valve is a check valve so constructed as to allow complete suction through the intake pipe on the intake stroke and to allow expulsion of any excess fluid within the combustion chamber on the compression stroke. Sparkplugs are to be installed in the balance of the sparkplug holes.

b. Remove the sparkplugs from their shipping container. Vapor degrease, using trichloroethylene (Specification MIL-T-7003), or equivalent, the sparkplugs for one to three minutes (a longer period is not harmful). Vapor degreasing is desirable to clean the plugs and remove any accumulated moisture. After inspecting the electrode gap (.011-.014 inch), bomb check each sparkplug on a BG M519 tester (or equivalent) at 200 psi. Observe the plug to make certain that a steady spark occurs at the electrodes. Reject any plug that fails to fire steadily at 200 psi or shows any indication of the plug's firing below the electrodes.

WARNING

Avoid prolonged breathing of trichloroethylene vapors and prolonged or repeated contact with skin. Observe fire precautions.

c. Apply a light coating of graphite base anti-seize thread compound (Specification MIL-T-5544) sparingly as a thin film on the shell threads, using a small brush [Figure 4–23].

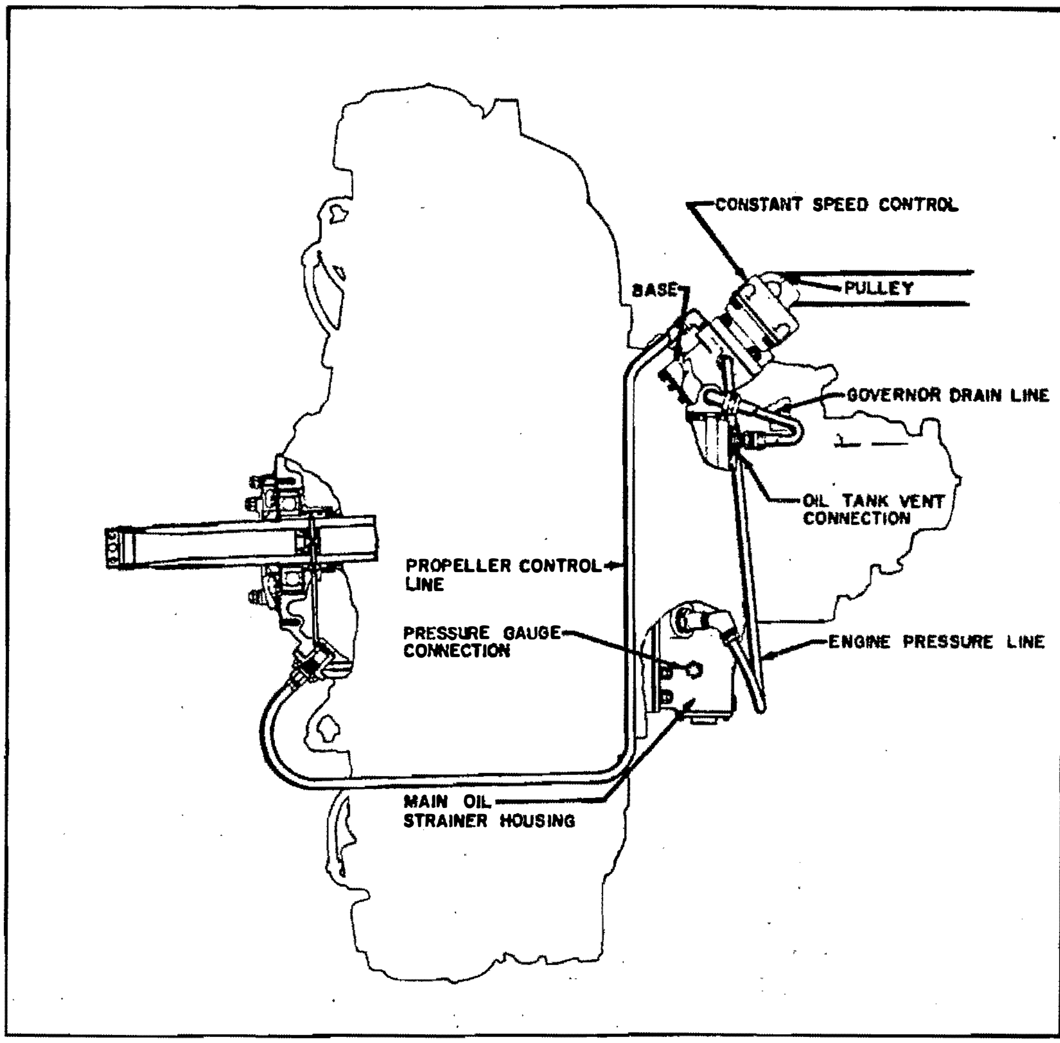


Figure 4—21. Schematic Governor — Constant Speed

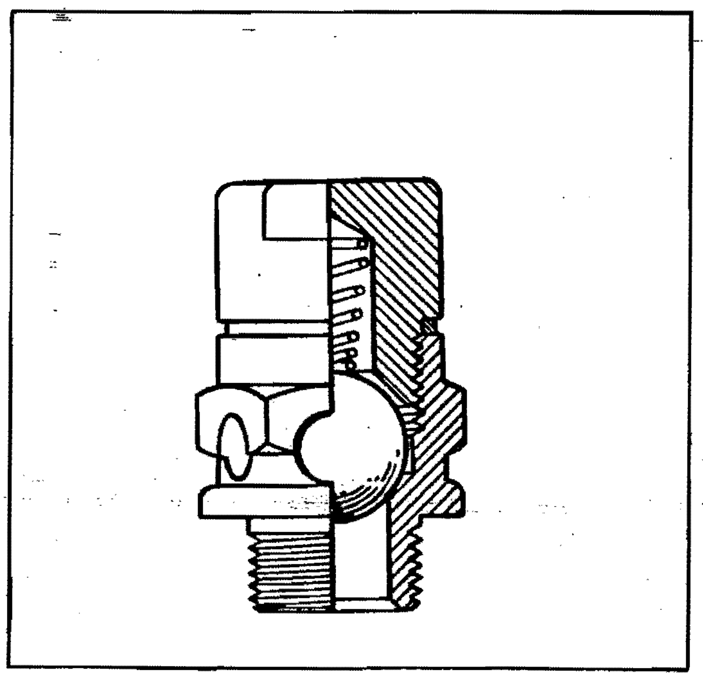


Figure 4—22. Depreservation Valve

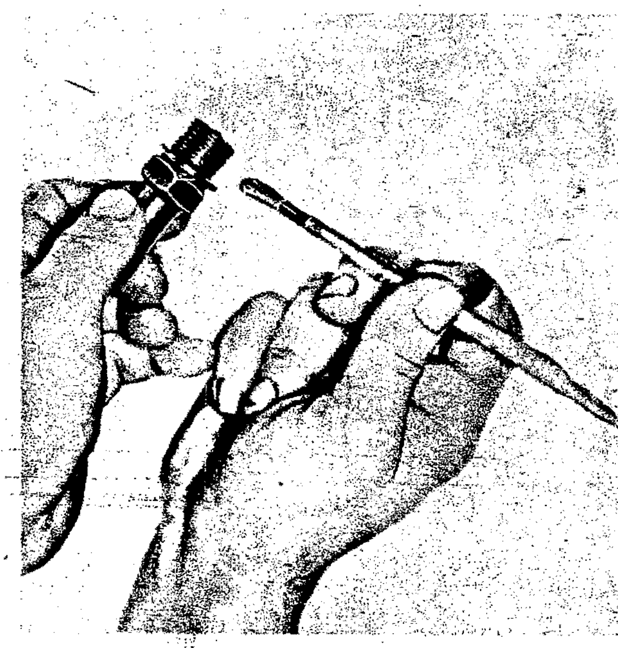


Figure 4—23. Applying Compound to Sparkplug

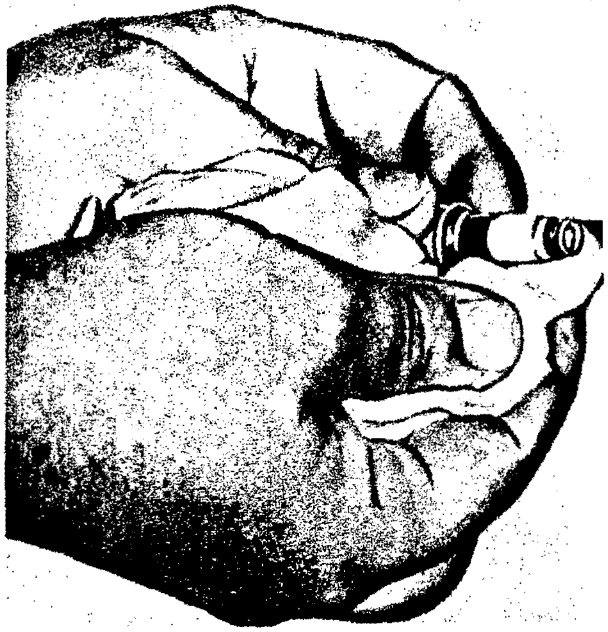


Figure 4–24. Compound to Connector with Cloth

CAUTION

Never allow anti-seize compound to get on the electrodes since this compound is conductive and will short out the plug. The anti-seize compound *must not* be applied to the barrel end threads.

d. Visually inspect the condition of the sparkplug insert and make certain that the top of the sparkplug hole is clean and smooth.

e. Making certain that there is a serviceable copper gasket (only one) on the sparkplug, screw the plug into the cylinder with the fingers until the plug bottoms on the gasket. If the plug does not screw in easily, remove the plug and inspect the plug threads. Minor imperfections of sparkplug threads should be corrected, where possible, by using a small three-cornered file. Tighten the plug to the recommended torque, using PWA-2006, PWA-2397, or PWA-2399 Wrench together with PWA-2398 or PWA-2411 Handle.

f. Remove the plastic protector from the sparkplug lead connectors.

g. Wipe the hands dry; then, using a clean, dry cloth, wipe the connector clean. If necessary moisten the cloth with dry cleaning solvent (Specification P-S-661) or equivalent.

CAUTION

Never use chlorinated solvents, Alcohol, or Acetone.

h. Visually inspect the connector insulator and spring. Do not touch with the fingers: If desired, apply a light film of insulating compound (Specification MIL-I-8660) to the connector by means of a clean cloth (*Figure 4–24*).

WARNING

The insulating compound contains minutely ground silica and mica which may act as irritants to the eyes and skin. When compound is handled frequently, it is suggested that gloves be worn.

i. Without touching the connector insulator or spring with the fingers, install the connector in the sparkplug barrel. Be very careful that the connector is inserted straight into the barrel and not "cocked," since this can result in a cracked insulator or sparkplug barrel.

j. Run the sparkplug lead coupling nut down finger tight. Hold the lead in proper position and tighten the coupling nut to the recommended torque, using PWA 1683 Wrench. Never use an open-end wrench, since damage to the barrel insulator may result from side loading.

k. Check the sparkplug leads to be sure that they do not interfere with the engine and are not twisted.

4–53. EXHAUST COLLECTOR RING. Remove the exhaust port covers and install the exhaust collector ring.

4–54. CARBURETOR. If the carburetor has been prepared for storage, it should be thoroughly flushed. Fill the carburetor through the fuel inlet opening with gasoline (Specification VV-G-109); then rock it back and forth. Remove the drain plug and allow the gasoline to drain. Repeat this procedure as many times as necessary to ensure that the storage oil has been completely washed. Reinstall the drain plug and lockwire all necessary parts. Remove the carburetor adapter cover from the engine and remove any dehydrating agent from the carburetor opening in the engine; then install the carburetor.

4–55. EXTERNAL CLEANING. If necessary, wash the exterior of the engine thoroughly with kerosene (Specification VV-K-211) or cleaning solvent (Specification P-S-661) being careful to keep the cleaning fluid away from the ignition manifold and magnetos.

WARNING

Avoid prolonged breathing of solvent and kerosene vapors and prolonged or repeated contact with skin. Observe fire precautions.

4–56. MAGNETO GROUND LEADS. Lightly coat the magneto ground spring connectors with insulation compound (Specification MIL-I-8660). Insert a ground connector into the ground terminal of each magneto. Screw the connector cap onto the ground terminal threads and secure.

WARNING

The Insulating Compound contains minutely ground silica and mica which may act as irritants to the eyes and skin. When compound is handled frequently, it is suggested that gloves be worn.

4–57. INSTALLATION OF ENGINE. Raise the engine carefully by means of a chain hoist (two tons minimum) and guide the engine and mount into position in the airplane. Bolt the engine mount to the airplane. Attach all fuel, oil, and control lines to their connections.

4–58. FUEL AND OIL TANK SERVICING. Service the aircraft fuel and oil tanks with the proper grade of fuel and oil as specified in Section III. After the oil tank has been serviced, turn the engine through several times in order to prime the oil lines and the oil pump.

4–59. PRESTARTING INSPECTION. Before starting an engine for the first time after installation, the following procedure should be observed: Check the magneto ground wires for proper connection. Determine that the terminal marked GRD on the ignition switch is connected to the airplane structure. Inspect all mounting bolts and nuts on both the engine and mount to be certain that they are tight and properly locked. Inspect the fuel and oil pressure gages, tachometer, thermometer and thermocouple for proper connection. Inspect all fuel, oil, and primer lines and connections for working order and proper connections in accordance with the fuel and oil system diagram and the marking on the fuel valves. Inspect the throttle and mixture controls for proper connections and operate them to determine that they function smoothly over the entire operating range. Open the valves and operate the auxiliary pump and check for fuel leaks. During this latter check, the mixture control must be held in the Idle Cut-Off position.

4–60. INITIAL GROUND RUN.

4–61. GENERAL.

4–62. The initial run-in should preferably be made with no cowling over the engine accessory compartment. When practicable, keep the airplane headed into the wind during all ground running. It is recommended that all ground operation be conducted with the engine cowling installed since the overall engine cooling is dependent on the airflow across the engine with cowling installed. While it is possible to maintain cylinder head temperatures within limits at low powers without engine cowling, it is possible that cylinder barrel temperatures will be exceeded due to the reduced airflow.

CAUTION

If the barrel temperatures are exceeded the oil film may be destroyed with resultant ring and cylinder barrel damage.

4–63. If protector caps have not already been installed, cap (or ground) the leads to the depreservation valve cylinders with sparkplug terminal protectors before rotating the propeller. Rotate the propeller at least 6 revolutions. Start the engine in accordance with the starting instructions set forth in paragraph 6–33 and operates the engine at 850 rpm for approximately 30 seconds. Replace the depreservation valves with sparkplugs and connect their leads. Refer to paragraph 7–45 and 7–46.

4–64. INITIAL GROUND RUN-IN.

4–65. Start the engine; then run the engine slowly (850 to 900 rpm) in order to accomplish a gradual warm-up. During this run it may be necessary to adjust the carburetor idling mixture strength and idling speed as directed in paragraph 7–32. After the engine has been warmed up and is functioning normally, run it approximately 875 rpm for 1 hour. Then increase the speed to 1600 to 1800 rpm for 15 minutes.

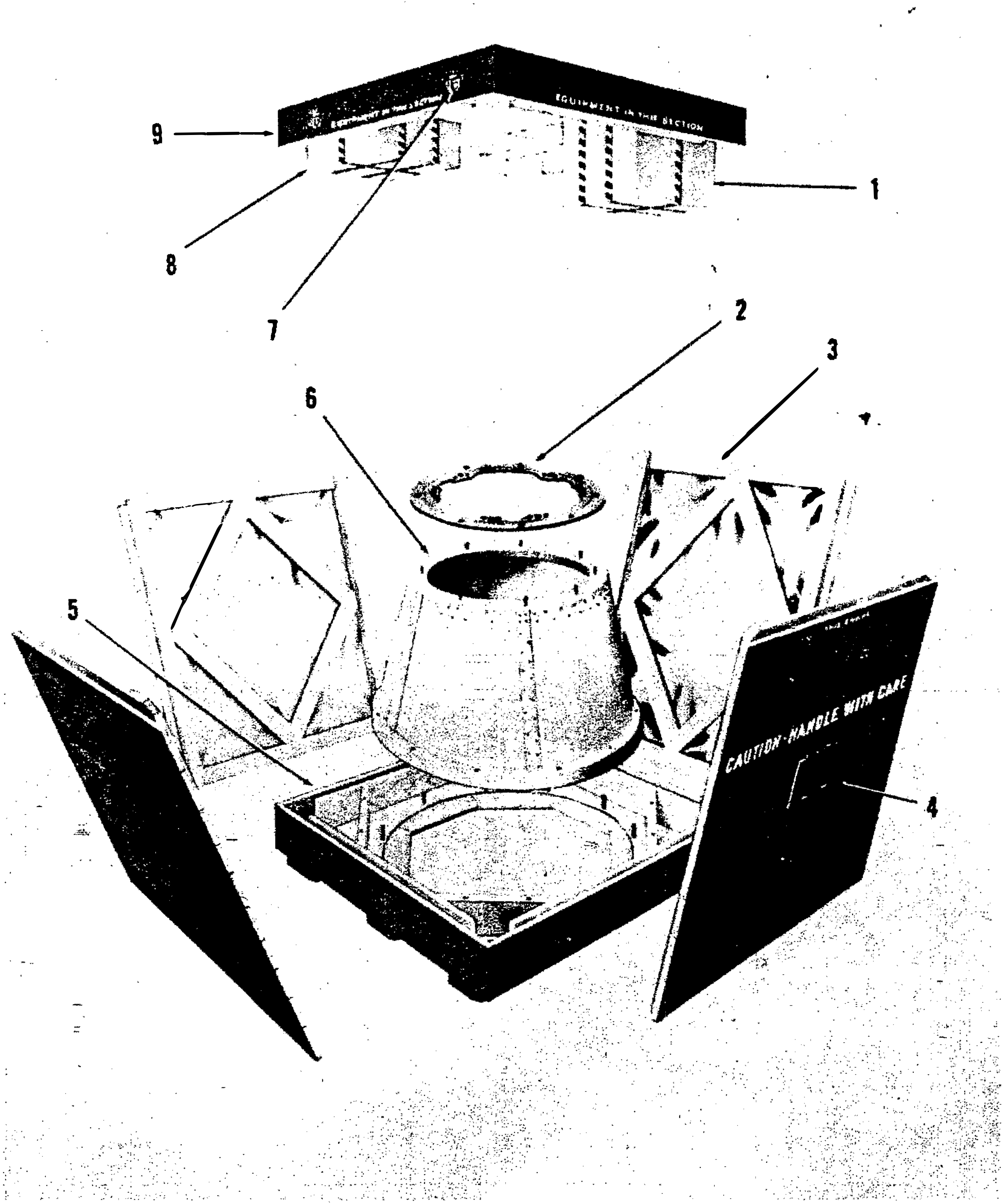
4–66. After the preceding operation, stop the engine and inspect for leaks, loose nuts, and condition of parts.

4–67. Remove the pressure and scavenge oil strainer, inspect and clean.

4–68. Ground test should be conducted in accordance with the instructions under "Specific Ground Checks" paragraph 6–38.

4–69. Take-off power and speed used for new and newly overhauled engines should be limited to the minimum practicable consistent with safety during the first ten hours of operation. Likewise, high power climbs, high BMEP lean mixture cruising (high manifold pressure) and overspeeding should be avoided during this period, except in case of emergency. Higher than normal cylinder temperatures may be evident for the first several hours of operation until rings are properly seated, and particular care should be taken to insure that specified temperature and manifold pressure limits are not exceeded.

4–70. Deleted.



1. Carburetor Carton
2. Engine Mounting Plate
3. Side Panel
4. Inspection Port
5. Base
6. Support Cone
7. Cover Lifting Rings
8. Accessories Carton
9. Cover

Figure 4—25. Exploded View of Packing Case

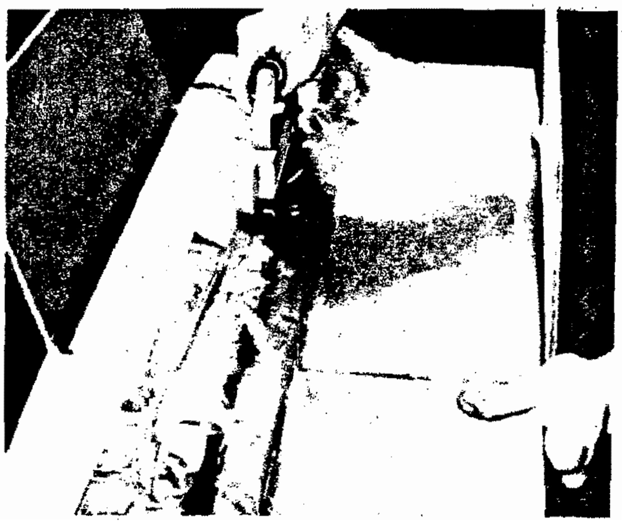


Figure 4–26. Seal Carburetor Packing Case

4–71. PACKING [Figure 4–25].

4–72. GENERAL. After the engine and accessories have been prepared for storage, they should be packed in the packing case. The use of a protective envelope eliminates the need for covering the outside metal parts with a coating of grease or other anticorrosive compounds. At low temperatures, the protective envelopes tend to become stiff, thereby becoming more vulnerable to rupture and presenting difficulties in handling. This condition may be overcome by handling the envelopes where the temperature is maintained at 20°C (68°F) or higher.

CAUTION

Be sure that shipping plugs, caps, and covers which are installed on the engine in place of flight equipment are painted yellow for easy visual identification.

4–73. PACKING THE CARBURETOR.

a. Place the carburetor in its original packing carton with the moisture resistant, protective lining. Attach the carburetor warning tag advising that it has been completely slushed with preservative oil. Attach a 1-pound bag of desiccants (Specification MIL-D-3464) to the carburetor. Expel as much trapped air as possible before sealing the lining. Seal the edges of the lining with the sealing iron [Figure 4–26] and close the flaps of the carton.

b. If a protective lining is not available for use in the carton, attach a 1 pound bag of dehydrating agent to the carburetor and wrap the carburetor in barrier material (Specification MIL-B-121); then wrap it in heavy wrapping paper and place it in a bag of waterproof crepe paper. The carburetor may then be packed securely in a carton.

c. Secure the carburetor packing carton to the engine packing case cover with steel straps or by blocking it into position with wooden strips.

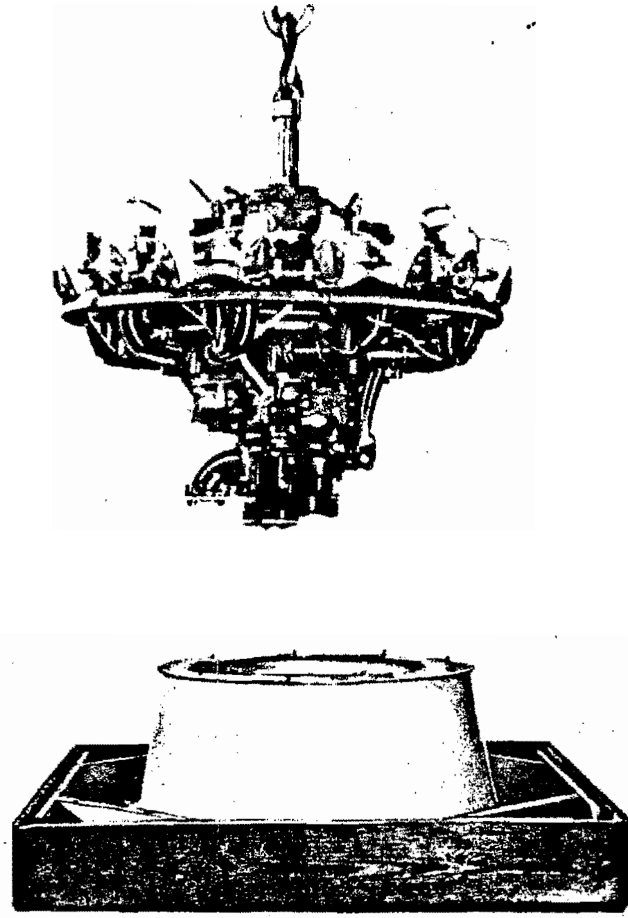


Figure 4–27. Shipping Base and Cone in Position

4–74. PACKING THE ACCESSORIES. All accessories such as sparkplugs, tubes, carburetor screens, and miscellaneous small parts which are detached from the engine for shipment should be packed in a single container with a moisture resistant protective lining. Insert 1/2-pound bag of desiccants (Specification MIL-D-3464) and expel as much trapped air as possible; then fold edges of the lining and seal tightly. Close and seal cover of carton; then secure it in the special partition on one side of case. If desired, the carton may be shipped separately from the engine packing case.

4–75. PACKING THE ENGINE.

a. Unfasten and remove the engine from the stand, using PWA-520 Lifting Eye, and hoist with a minimum capacity of two tons.

b. Place the support cone on the packing case base, fitting the holes in the cone over the studs in the base. Fasten the cone to the base with washers and nuts. Place the packing case mounting plate in position but do not secure it.

c. Place the engine case base with the support cone attached and the mounting plate in position, under the engine [Figure 4–27]. Carefully spread the protective

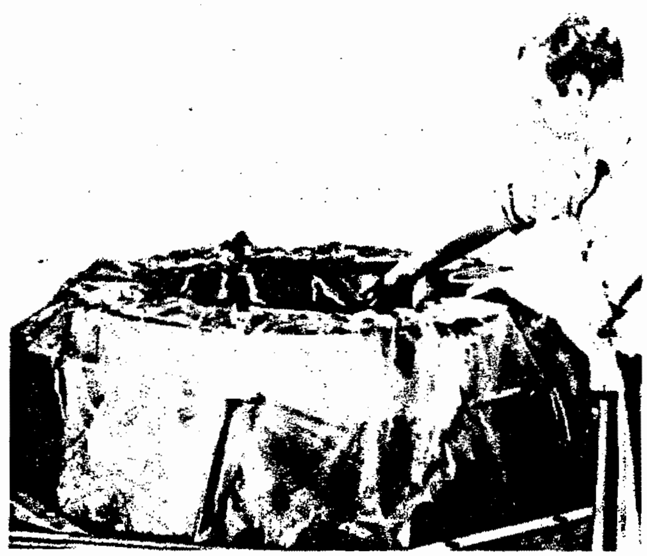


Figure 4—28. Spread Envelope Inside Support Cone

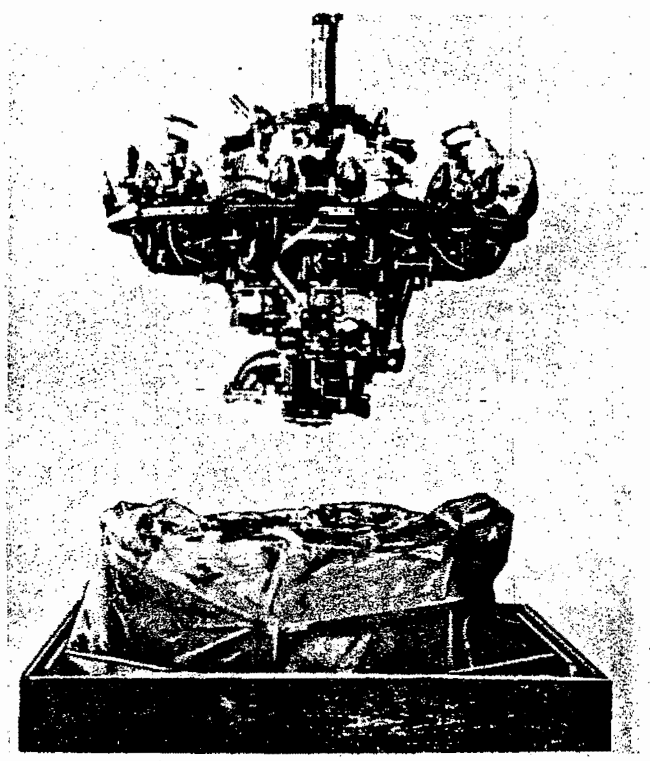


Figure 4—29. Lowering Engine onto Mount Plate

envelope inside the support cone *[Figure 4—28]*, locating the large reinforcing washers over the holes in the mounting plate.

d. Carefully lower the engine onto the mounting plate *[Figure 4—29]*, secure nuts to two opposite bolts, raise the engine and mounting plate *[Figure 4—30]* and fasten the remaining bolts to the mounting plate.

e. Cover with tape any protruding nuts, studs, or lockwire which might damage the protective envelope.

f. Fasten two 1-pound bags of desiccants (Specification MIL-D-3464) to each cylinder *[Figure 4—31]*. Wrap crepe paper around the power section; then attach the humidity indicator to the crepe paper *[Figure 4—32]*.

g. Lower the engine onto the cone and fasten the mounting plate to the cone. Clean the exposed surface of the propeller shaft being careful to remove fingerprints. Coat the shaft thoroughly with a soft film of corrosion preventive compound (Specification MIL-C-14201).

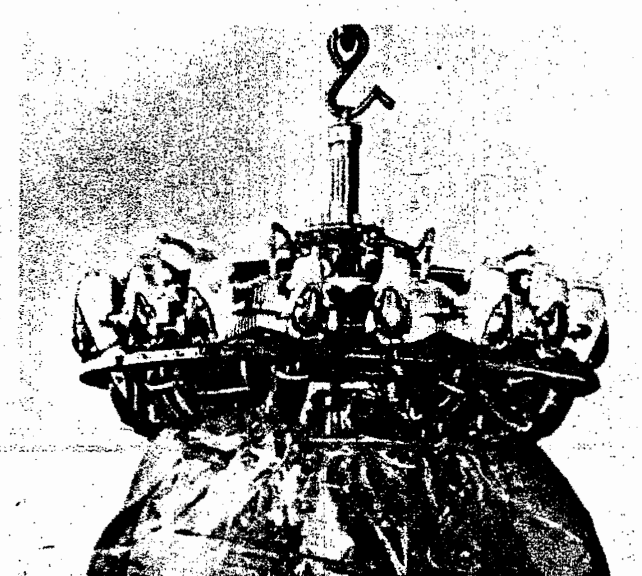


Figure 4—30. Raise Engine and Mount Plate

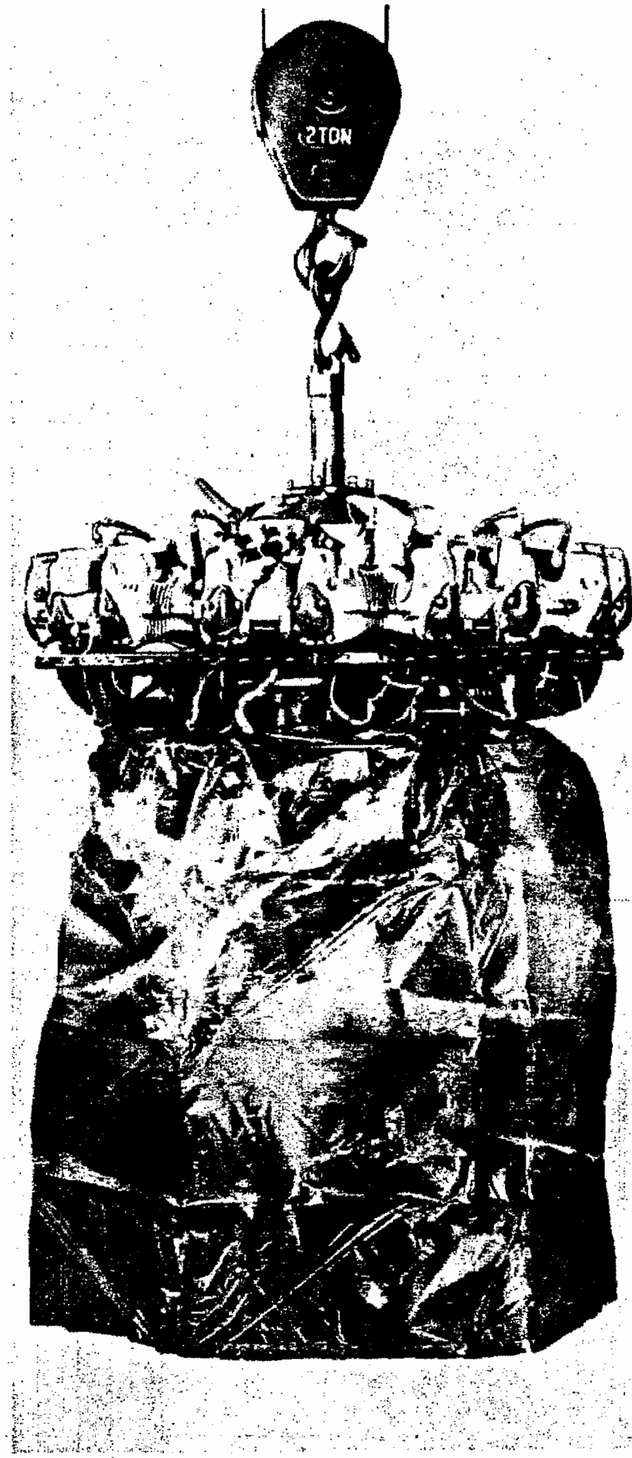


Figure 4–31. Fasten Dehydrative Bags to Cylinder

h. Wrap the shaft with barrier material (Specification MIL-B-121); then secure with tape (Specification PPP-T-60) [*Figure 4–33*]. Bring the protective envelope up around the engine. Install the spacer [*Figure 4–34*], place the envelope reinforced opening on the

Figure 4–32. Attach Humidity – Indicator in Place

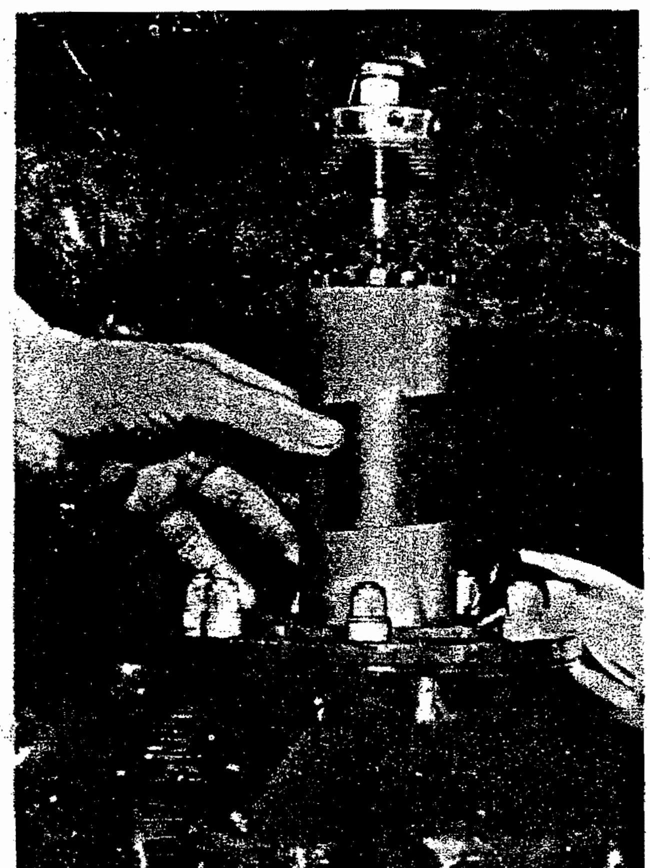


Figure 4–33. Secure Paper on Shaft

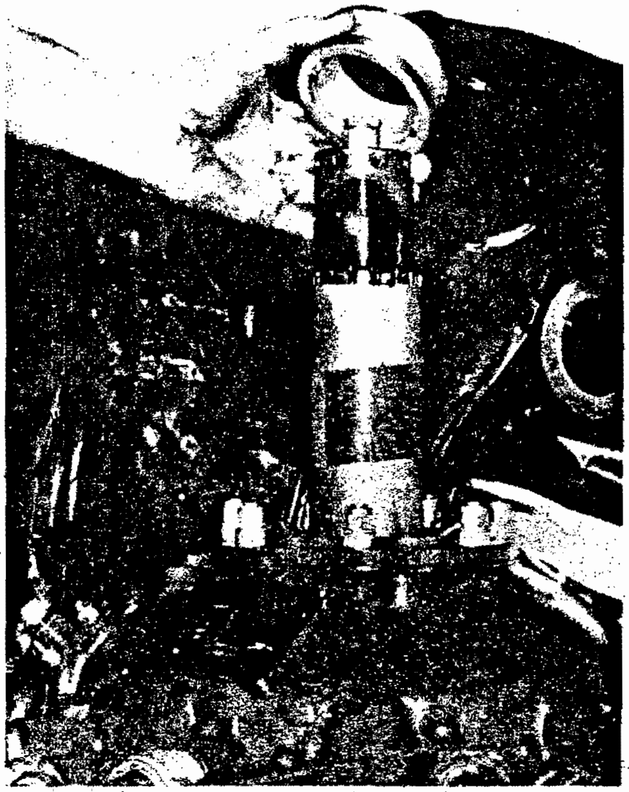


Figure 4–34. Install Spacer

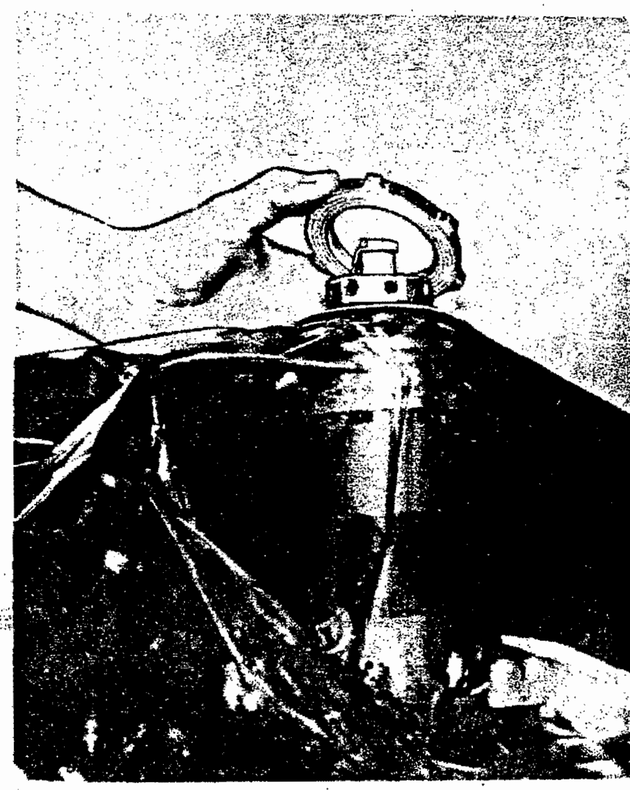


Figure 4–35. Screw On Spanner Nut

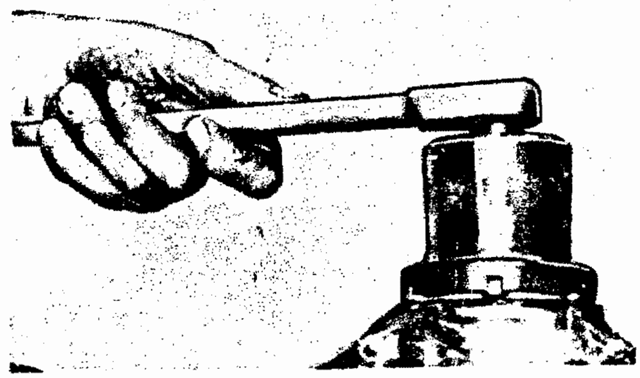


Figure 4–36. Tighten Spanner Nut

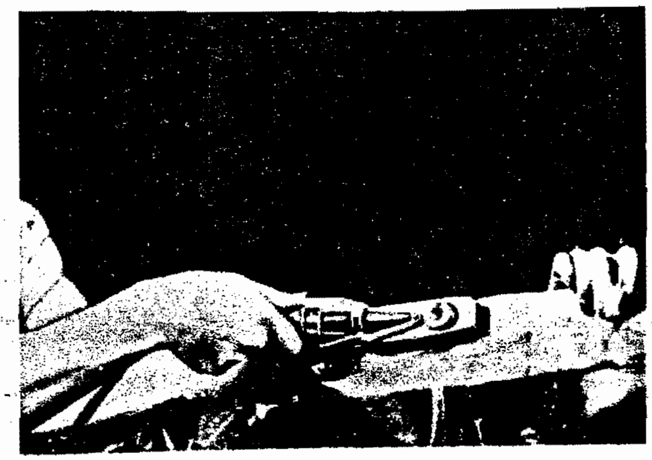


Figure 4–37. Sealing Envelope

Figure 4–38. Install Side Panels in Case

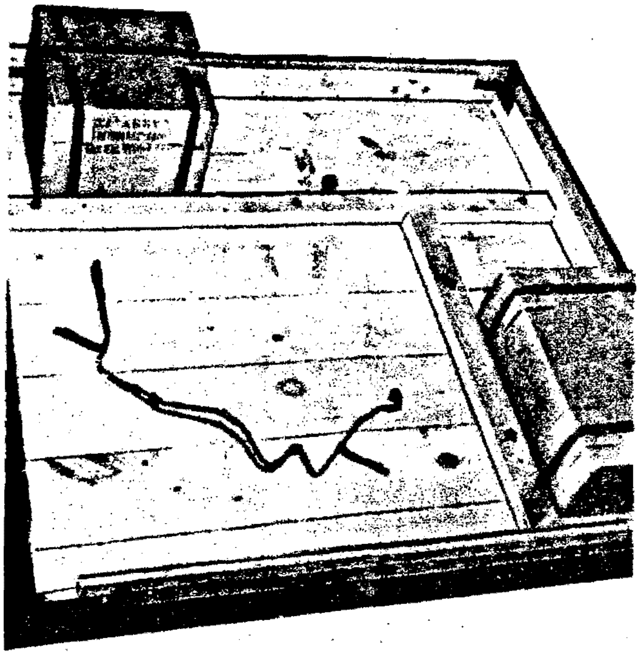


Figure 4—39. Accessories Attached to Cover

Figure 4—40. Lowering Cover into Position

Figure 4—41. Tightening Steel Straps

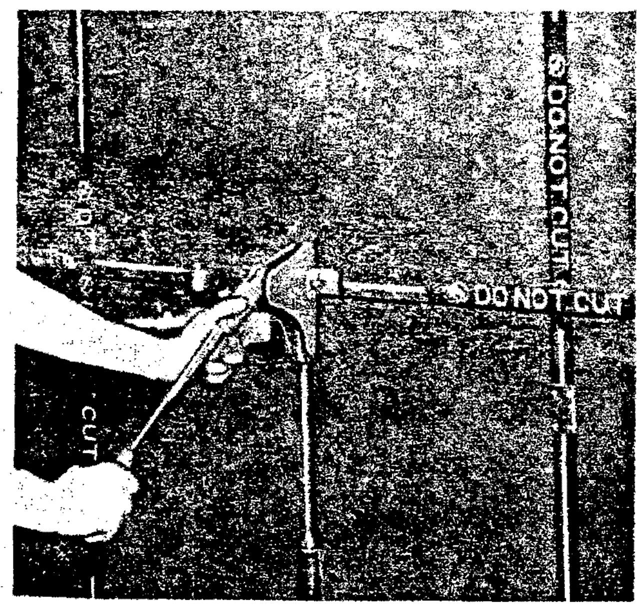


Figure 4—42. Securing Straps With A Crimping Tool

propeller shaft, and screw the spanner nut *[Figure 4—35]* tight against the envelope *[Figure 4—36]*. Install the protector cap and seal the protective envelope *[Figure 4—37]*, withdrawing as much air as posible without shrinking the envelope tight against the engine. Fasten the excess envelope material around the propeller shaft.

i. Install the four side panels in the base *[Figure 4—38]*, attach the carburetor and accessories to the packing case cover *[Figure 4—39]*, and lower it in position *[Figure 4—40]*. Pass two steel straps over the top and under the bottom of the case, tighten *[Figure 4—41]*, and secure with crimping tool *[Figure 4—42]*. Pass the third strap around the case horizontally, tighten and secure with crimping tool. Place the engine log data sheets behind the inspection port cover and wire the cover.

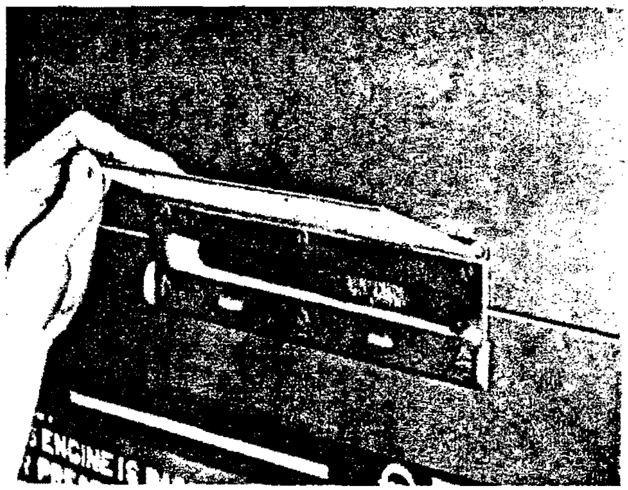


Figure 4—43. Inspecting Humidity Indicator

j. The engine should be regularly inspected *[Figure 4—33]* by means of the humidity indicator, which is a color chart showing the safe and unsafe color ranges of the dehydrating agent. The frequency with which engines in storage should be inspected will depend largely upon storage conditions. This agent is a deep blue when dry, ranging to a lighter blue and into pink as it becomes moist. When the relative humidity exceeds 20 percent, the dehydrating agent assumes an unsafe color as shown on the color shart. If the humidity indicator registers unsafe, replace all old dehydrating agent and install a new humidity indicator.

4—76. WEIGHT AND DIMENSIONS. The dimensions for both domestic and overseas packing cases are 54⅛ x 54⅛ x 52¾ inches. The weight of the packing case with the engine approximates 1251 pounds.

SECTION V

ENGINE TROUBLES AND THEIR REMEDIES

5—1. GENERAL.

5—2. This section outlines the most common symptoms of engine troubles, their possible causes, and remedies. It is intended to guide and expedite the work of the trouble shooter. Locating and correcting engine troubles should be accomplished by first studying the symptoms carefully and then checking each possible cause, beginning with the most probable, until the exact cause of the trouble is determined. Because some engine troubles are evident in only one range of engine speed, the engine's operation should be observed at low, medium, and high speeds, whenever possible.

5—3. Before attempting to work on an engine which has been reported as faulty in flight, consult the pilot's flight report and all other available sources for any pertinent information which might give a clue to the cause of the trouble.

5—4. The term "trouble shooting", as applied to aircraft engines, may be defined as the systematic and thorough analysis of the symptoms of engine malfunctioning in order to ascertain the cause or causes and thereby to determine the proper remedy. Generally speaking, engine trouble is caused by:

1. Improper maintenance or operation.
2. Structural failure.

5–5. Maintenance personnel must know the engines for which they are responsible and should conform with the recommendations of the manufacturer, who provides Specific Operating Instructions. If these are conscientiously adhered to, the life of the engine will be greatly prolonged, the airplane operated more efficiently, and flight personnel assured of greater safety. Therefore, the necessity for care and thoroughness in the inspection and maintenance of aircraft engines cannot be overstressed. Good engine operation cannot be expected if maintenance work is slipshod. The two major items are:

1. Cleanliness.
2. Care or exactness.

5–6. Structural failures may be the result of improper maintenance or operation. Malfunctioning of such parts of the engine as an oil pump, pressure relief valve or carburetor; fatigue failure due to the action of stresses caused by forces or heat which exceed the specified limits — these and other factors result in failure.

5–7. Effective trouble shooting follows these simple rules:

1. A careful initial analysis of symptoms. This includes a study of the pilot's flight report and all other available sources for any pertinent information which might give a clue to the cause of the trouble.

2. A systematic check of each probable cause. Since some troubles are evident in only one range of engine speed, the operation should be observed at low, medium and high speeds.

3. The segregation of the cause of the symptoms to one or more of the systems of the powerplant installation. These systems are principally as follows:

1. THE IGNITION SYSTEM.

2. THE FUEL AND INDUCTION SYSTEM. This system comprises that part of the powerplant which handles the air from the intake scoop to the exhaust tailpipe and the fuel from the tank to its mixture with air.

3. THE LUBRICATION SYSTEM.

4. ENGINE AND NACELLE. This system includes combustion chambers, connecting rods, crankshaft, gear trains, crankcase supports, and engine mounting.

5. THE COOLING AIR SYSTEM. This system includes baffles, cowling, oil cooler, and controls.

6. THE PROPELLER.

7. ACCESSORIES. In this category are comprehended all electrical, hydraulic and pneumatic accessories, such as pumps, starters, etc.

8. COCKPIT CONTROLS OF ABOVE SYSTEMS.

5–8. FUNCTION OF THE FUEL SYSTEM.

5–9. The function of the fuel system is to furnish and adequate supply of clean fuel in a uniform, continuous flow at the required pressure. Clean fuel means freedom from water vapor, dirt or other sediment that is likely to clog the jets or in any way to disrupt uniform metering of the carburetor. In general, the system must be designed, and its component parts selected for, the particular requirements of the airplane. The pressure, altitude and the airplane maneuvering characteristics are governing factors.

5–10. BASIC REQUIREMENTS.

5–11. The basic requirements for a satisfactory fuel system are:

1. The maintenance of a positive head of fuel at the carburetor with an absolute minimum of air and vapor content.

2. The pressure should be specified for the particular carburetor type. The Stromberg float type requires 4 to 6 psi.

3. The fuel system should be as simple, fireproof, and foolproof as possible, with a minimum of bends, piping, fittings, and accessories.

4. The system components should not be liable to deterioration or failure due to the fuel constituents, vibration, low temperature or other destructive factors.

5. The system should function during all operations and maneuvers which the airplane might perform, and throughout the accelerations or decelerations which it might experience.

6. Adequate accessibility should be incorporated in the installation to permit inspection and servicing, and to permit replacement of any fuel system component without partially disassembling the nacelle or the airplane structure.

CAUTION

Mixed controls and throttles must have full travel and not hit the ends of the gates on stand. Mixture control should line up with the appropriate marks on stand when the control arm enters the detents on carburetor. Controls should line up in any set position and have freedom of movement.

Note

If strainers appear exceptionally dirty, flush carburetor.

NOTE ON ENGINE STARTING

First, see engine manufacturer's instructions and the recommended starting procedure. In all cases of failure of the starting system, investigate and remedy the trouble before making any attempt to operate the system.

5–12. THE USE OF THE THROTTLE IN ENGINE STARTING PROCEDURE.

5–13. Throttle operation during engine start is a matter of experience. For most engine starts, the throttle position should never be more than ¼ open and in many cases a "cracked" throttle is sufficient. In all cases, however, throttle "pumping" during engine start will contribute nothing to the ease of starting. After the preliminary throttle position has been established, it should not be necessary to change this position until the engine is running smoothly. After an unsuccessful engine start due to excessive priming, with float type carburetors, the throttle may be used to clear the blower case of fuel vapors. In this case, the throttle is opened fully while the engine is being cranked. The open throttle prevents fuel being drawn through the float type idle system, and the cranking should be followed only with the switch "OFF", since the aircraft or surroundings might be damaged if the engine is started with throttle wide open.

5—14. BASIC ENGINE STARTING PROCEDURE.

1. Battery or Power Source "Open"
   Air/Intake System "Open"
   Exhaust System "Open"
   Cooling Air System "Open"
   Fuel System "Open"
   Oil System "Open"
2. Starter arm switch to "START" position.
3. Engine selector switch to "ENGINE BEING STARTED".
4. Engage direct cranking starter and watch propeller motion. If propeller shows signs of hesitation in turning, or stops, disengage starter and investigate. With inertia starters, pull through by hand with throttle "Open", and ignition "Off".
5. Booster pump "ON".
6. After geared engine has turned freely for 15 to 20 revolutions for a cold engine, or 8 to 10 revolutions for an engine which has been run within the previous two hours, or half as many revolutions for direct drive engines, turn ignition switch to "BOTH". This is to pump oil to gear trains and rocker boxes that have drained; also to clear engine of oil, fuel, and fuel fumes.

Note

$$\frac{\text{By definition, Prop. Rev.}}{\text{Engine Rev.}} = \text{Gear Ratio}$$

Rearranging, Prop. Revs. = (Engine Revs.) (Gear Ratio)
No. of Blades = (Blades Per Prop.) (Prop. Revs.)
Substituting for (Prop. Revs.) from above: No. of blades = (Blades Per Prop) (Engine Revs) (Gear Ratio).

7. After switch is "ON", depress ignition boost switch and prime as required to start engine.
8. Move mixture control to "RICH" before or while cranking with throttle practically closed.
9. As engine rpm passes 500, ease mixture control out of "IDLE" towards the "RICH" position. In some instances with prime still on, it may be best to allow the engine to smooth out at or below the lean position before moving the mixture control to the rich position and releasing the prime.

5—15. TROUBLE SHOOTING PRESENCE OF METAL PARTICLES IN THE ENGINE.

5—16. SIGNIFICANCE. The presence of metal particles on the oil screen and in the oil sump usually indicates failure of a part within the engine. Whether the engine is suitable for further service depends upon the kind, form and the quantity of the metal particles found. Granular metal particles in any amount greater than a trace usually indicate an imminent part failure.

Note

In case of an internal engine failure, metal chips and foreign material will be deposited throughout the aircraft oil system. If these contaminating materials are not removed before the replacement engine is installed, the latter will probably be damaged and an internal failure result. Experience has shown that the only satisfactory method of cleaning the oil system is to disassemble it sufficiently so that all surfaces where chips may be lodged can be cleaned and visually inspected to make sure that the foreign material has been eliminated. In particular, it is recommended that sufficient tubes of the oil cooler be removed to insure positively that all tubes are free of metal particles, as it has been found that methods of cleaning which involve reverse or alternate flushing accompanied by shaking the oil cooler are not sufficiently effective.

5—17. 1 TROUBLE: Metal Particles in Screen and Sump
(Splinter or Granular Form)

Note

A visual inspection as to color and hardness will occasionally suffice to determine the kind of metal present. When visual inspection does not positively identify the metal, the kind of metal present may be determined by the few simple tests described in the following chart:

Kind of Particle	Identification	Action Required
1. Steel	May be isolated by means of a permanent magnet.	Engine removal.

5—17. I TROUBLE: Metal Particles in Screen and Sump, Cont'd.

Kind of Particle	Identification	Action Required
2. Tin	Identified by low melting point. Use a clean soldering iron heated to about 500°F and tinned with 50-50 solder (50% lead — 50% tin). Wipe off the excess solder. A tin particle dropped onto the heated iron will melt and fuse with the solder.	No action required. Since tin is used only in plating, granular tin will not be found.

CAUTION

Care will be exercised to avoid excessive overheating of the iron during this test.

Kind of Particle	Identification	Action Required
3. Aluminum	Presence may be determined by reaction with hydrochloric (muriatic) acid producing a rapid emission of bubbles. Particle will disintegrate and form a black residue (aluminum chloride).	May indicate piston failure. Inspect cylinders by visual examination of cylinder bores. Locate faulty piston with compression check. If a faulty piston is found, remove the engine.
4. Silver	Produces whitish fog when dropped into nitric acid.	Silver particles in quantity indicate masterod bearing failure, requiring engine removal.
5. Copper or Bronze	Produces bright green cloud in nitric acid.	Copper or bronze particles in quantity indicate disintegration of a bushing or valve guide, requiring engine removal.

5—18. II TROUBLE: Metal Flakes in Screen and Sump

Kind of Metal Flake	Quantity and/or Size	Action Required
1. Steel	Any quantity.	Engine removal.

Note

Ring fuzz may be found in the oil sump of any normal engine or on the main oil screen. These very fine hair-like particles are the result of normal seating of the piston rings and cylinders and are not cause for any concern regarding the serviceability of the engine.

Kind of Metal Flake	Quantity and/or Size	Action Required
2. Tin	Any quantity.	None.

Note

Since tin is used only in plating engine parts and in thickness not greater than .0005", granular tin will not be found.

Kind of Metal Flake	Quantity and/or Size	Action Required
3. Aluminum	1/16" x 3/16" or smaller.	Engine removal not required. Make a careful inspection of the cylinders by visual examination of the cylinder bores, and a compression check in an effort to locate the faulty piston. If a faulty piston is found, remove the engine.
4. Silver	Not over 1/16" x 3/16" and not exceeding 10 in number.	None.

Note

Silver is used in plating form on numerous parts. Since silver is quite soft, some small flakes will occasionally be released due to the normal working of these parts. A very small quantity of silver from the masterod bearings will make a large number of tiny flakes as it passes through roller bearings or gears within the engine. Large quantities of silver flakes indicate an excessive loss of bearing or plating material, and the engine will be removed as a precautionary measure.

5—18. II TROUBLE: Metal Flakes in Screen and Sump, Cont'd

Kind of Metal Flake	Quantity and/or Size	Action Required
5. Copper or Bronze	1/16" x 3/16" in size and in quantities not exceeding 10 flakes.	None. This indicates normal result seating of bushings or valve guid
	Large quantities.	May indicate excessive loss of plating bushing material. Remove engine as precautionary measure.

5—19. IGNITION SYSTEM.

(Failure to Sta

CAUSES	REMEDIES

Note

This work need not be performed except when the housing is opened for other reasons or when engine malfunctioning, not attributable to other sources, is encountered.

CAUTION

In all cases of failure of the starting system, investigate and remedy the trouble before making any attempt to operate the system.

MALFUNCTIONING SPARKPLUGS

Carbon coating.	Clean plugs.
Closed sparkplug gap.	Replace plugs. Refer to pages 88, 89.
Worn sparkplug bushings and gaskets.	Replace with specified bushings and gaskets.
Wet sparkplug lead terminal sleeves.	Dry sleeves.
Corroded or damaged ignition cable caused by moisture.	Replace cable.
Loose wiring terminals and elbows.	Tighten connections.
Burned shell electrodes.	Replace sparkplugs. Refer to pages 88, 89.
Damaged sparkplugs.	Replace sparkplugs. Refer to pages 88, 89.

NOTE ON INSTALLATION OF PLUGS

CAUTION

Be sure that sparkplug inserts are clean, that the correct sparkplug gasket or thermocouple is installed and that sparkplug can be turned all the way down by hand. Tighten to the correct value with a torque wrench. Plugs installed too tightly may be distorted or insulation cracked, thereby affecting engine operation.

Defective sparkplug lead connectors.	Clean dirty connectors with a clean dry cloth. Replace damaged co nectors. If necessary, dry cleaning solvent (Specification P-S-661) ma be used for cleaning. Replace compound as described on page 8
Burned sparkplug leads, defective ignition cable assembly, or moisture in the ignition manifold assembly.	Make continuity and high voltage test on manifold. Replace cab assembly or leads, if necessary. If continuity test shows leads to b unbroken, check conduit for moisture. If moisture is found, dry o conduit by loosening conduit coupling nuts and applying heat or a blast.

5—19. IGNITION SYSTEM, Cont'd. **(Failure to Start)**

CAUSES	*REMEDIES*

Note

If a spark cannot be obtained at the sparkplugs, trace the current from the battery to the distributor. Check all terminals for security. If ammeter shows a heavy discharge upon turning the switch, it is an indication of a wiring or ignition short. If no flick of the ammeter is noticed when the engine is turned over it is an indication of an open circuit, defective or dirty coils.

Defective magneto ground leads.	Disconnect ground lead from each magneto. Attempt to start the engine. If engine starts, the magneto ground system is defective.

Note

Check to see that ignition switch is in "ON" position. If failure to start is caused by an internally defective magneto, replace this unit.

Defective starter.	If the starter jaw does not advance into engagement, check for worn oil seal and binding action between screw shaft and spline nut. Check the power source for correct voltage. Replace the control switch or relay, if it is inoperative. Inspect wiring, internal and external, for possible grounded, shorted, or broken leads and for burned, cracked or unserviceable insulation. Internal wiring replacement will require overhauling of the starter. If the commutator is unserviceable or not concentric or the armature open, shorted, or grounded, replace the starter.
Insufficient cranking speed.	Check batteries and starter. Connect booster battery. Replace starter and/or batteries, if necessary.
Moisture or oil in magneto or distributor.	Clean magneto distributor rotor with dry cleaning solvent (Specification P-S-661), using clean cloth. Wipe clean with dry cloth. Check vent lines and screens for foreign matter.

CAUTION

In order to avoid the possibility of over-lubrication or not getting the oil exactly where it is needed as might be the case when an oil can is used, the use of a hypodermic syringe is recommended. This not only assures that just the right amount of lubrication will be used, but also that the lubrication is placed exactly where desired.

Dirty, burned, or pitted breaker points.	Clean points with dry cleaning solvent (Specification P-S-661). Use clean, lint-free cloth. Replace points badly burned or pitted.
Ground manifold or lead from magneto ground connection to cockpit switch grounded.	Check wiring between ground connection and switch.
Magneto incorrectly timed to engine.	Check magneto timing. Refer to pages 85 and 86.
Defective booster.	Check wiring and connections. Replace defective coil, if necessary.
Defective wiring.	Examine wires for moisture, wear, breaks, and loose or incorrect connections. Repair or replace wire or connections as necessary.
Shorted dielectric parts (distributor heads, blocks or fingers).	This condition is started by the accumulation of acid deposits resulting from normal operation, and from deposits of perspiration and foreign material as a result of handling. It is therefore essential that the parts be lightly wiped with a clean cloth after handling and that they are to be cleaned and treated when necessary.

5–20. FUEL SYSTEM.

(Failure to Start)

CAUSES	REMEDIES

Note

Check carburetor specifications and setting to be sure specifications and setting are for the engine make and model on which the carburetor is installed. Do not change carburetor adjustments until satisfactory engine operation has been definitely established as resulting from carburetion.

CAUSES	REMEDIES
Insufficient fuel pressure.	Replace fuel shut-off valves not operating; check fuel-quantity indicator and check fuel tanks with dipstick; replace malfunctioning indicator; fill fuel tank to proper level; replace leaking lines and tighten connections. Check adjustment screw on fuel pump; increase fuel pressure by turning adjustment screw. Check fuel strainer. Check fuel flow to entrance of pump. Check flow and rotation directions of newly installed pump.
Lack of fuel or wrong grade of fuel.	Check fuel gage. Fill tank with recommended grade of fuel. Refer to page 25.
Fuel leaks.	Check lines, connections, joints and clamps. Replace defective parts.

Note

It is normally possible to locate a fuel leak very precisely by visual inspection while the tanks are full. In rare instances, the exact source of the leak may be hidden or very difficult to find. In such cases only, use of an air pressure test is indicated.

Some of the basic methods used to detect the cause of tank leaks are:

1. The *pressure check*, which requires drawing fuel from the tank and applying about three pounds per square inch of air pressure while soaping the external surfaces.

It is necessary to conduct the air test soon after the tank has been drained and ventilated, because a tank that has been allowed to dry out thoroughly will show numerous "fizz" leaks at rivets. Brushing soap solution over these areas will show small rings of foam or slowly forming bubbles. This is a normal condition and such "fizz" leaks must be ignored. The air test is not intended to discover leaks, but merely to locate leaks precisely in event such leakage cannot be traced to exact point of origin when the tanks are full.

During air test, therefore, the bubble fluid should be applied only to the area known to be leaking fuel. The leak may be large enough to blow away the bubble fluid without allowing bubbles to form. In this case, use a large soft bristle brush, dip it in the fluid, and draw it slowly across the affected area. The brush will restrict the air flow enough to allow bubbles to form as the tip of the brush passes over the leak.

WARNING

It should be remembered, following an air test, that the air under pressure in the tank is a potential explosion or fire hazard. MAKE CERTAIN THAT NO ELECTRICAL EQUIPMENT OR OTHER POSSIBLE SPARK SOURCE IS OPERATING IN THE AREA NEAR THE AIRPLANE, OR ON THE AIRPLANE, WHEN THE AIR UNDER PRESSURE IN THE FUEL TANK IS RELEASED.

2. The *blow-back* method wherein air pressure is applied to the exit point of the leak and the internal surfaces of the tank are soaped in order that bubbles may indicate the source of the leak.

3. *Fluorescent dyes* may be dissolved in solvents such as Varsol and forced through the leak by low pressure air or gravity, so that channels in the sealing material may be detected by the use of black light.

4. Leaks in upper surface corrugations can best be detected by drawing a sliding plug through the corrugation and filling that part above the plug with Varsol.

There may be additional methods to detect the presence and source of leaks, but all of them require the use of good judgment on the part of the tank maintenance crew. The removal of bubbles and blisters in the tank surfaces and the replacement or repair of small areas of defective material can usually be accomplished during regular maintenance.

5—20. FUEL SYSTEM, Cont'd. **(Failure to Start)**

CAUSES	REMEDIES

WARNING

The engine should not be started with a leaking carburetor because of the fire hazard involved. Defective carburetors should not be disassembled, but replaced.

CAUSES	REMEDIES
Overpriming (engine flooded).	With ignition "OFF" open throttle fully, and, using starter intermittently, turn engine over. Decrease priming time or strokes.
Primer inoperative.	Disconnect primer lines from distributor and operate primer to see if fuel flows from feed lines. Check primer lines or replace carburetor. Refer to page 106.

NOTE ON THE USE OF THE ENGINE PRIMER

Proper use of the engine primer is a matter of judgment developed from experience; the amount of priming required will vary with operating conditions, engine temperature, and general condition of the engine. Overpriming while cranking the engine allows fuel to exit from the exhaust system and drip to the engine shroud. After a short period of cranking with excessive prime, the engine fires and ignites the fuel which has collected on the shroud, causing an engine compartment fire. If fire breaks out as the engine starts or after the engine has started, keep the engine running.

CAUSES	REMEDIES
Incorrect mixture control setting (mixture too lean).	Adjust throttle and mixture controls.

Note

Before making an idle adjustment, and expecting to have good results, it is understood that the engine must be in good condition, namely: (1) Good compression on all cylinders; (2) Clean ignition, correctly timed; (3) Good fuel and induction system.

CAUSES	REMEDIES
Carburetor loose or leaking at the mounting flange.	Rectify external leaks, if possible. If leaks are internal, replace the carburetor. Refer to page 106.
Carburetor floods.	Place engine throttle lever in the idle position. If carburetor continues to flood while starting, replace carburetor [Refer to page 106]; check the fuel pump pressure before replacing with new carburetor. Check float level.
Contaminated fuel (water in fuel or incorrect grade of fuel).	Drain and refill with correct grade of fuel. Refer to page 25.
Clogged fuel lines.	Locate clogged lines, remove, clean, and reinstall.
Excessive booster pump operation.	Engine starting experience, especially in regions of extremely high ambient temperature, where short stop-overs do not allow engine to cool down adequately before being restarted, has shown that more successful engine starts can be achieved, if booster pump operation is limited to a very short period prior to cranking the engine. Limited booster pump operation will, under these circumstances, provide sufficient fuel vapor mixture and minimize the possibility of overloading the engine.
Air leaks or restrictions in induction system.	Check security of ducts, carburetor and intake pipes; check main air scoop for restrictions; check air induction by-pass valve for operation. Tighten all loose connections. Check carburetor air filters for foreign matter. Remove restrictions caused by foreign material. If necessary, replace air induction by-pass valve. Check security of carburetor and intake pipe nuts.
Blown or leaking gaskets.	Replace gaskets.
Blistered or cracked manifold.	Replace manifold.

5–21. IGNITION SYSTEM. (Rough Running)

CAUSES	REMEDIES

Note

Magnetos, ignition wire and sparkplugs give very little trouble, if they are clean and installed correctly.

CAUSES	REMEDIES
Defective sparkplugs.	Determine what plugs are defective by magneto check. (Refer to pag 77.) Remove plugs and replace them with new or reconditioned plug
Defective sparkplug lead connectors.	Clean dirty connectors with a clean dry cloth. Replace damaged con nectors. If necessary, dry cleaning solvent (Specification P-S-661 may be used for cleaning. Replace compound as directed on page 89

CAUTION

The following cautions should be observed when cleaning sparkplugs:

1. Never attempt to disassemble ceramic type plugs.

2. Align ground (side) electrodes with the indicator marks on the bottom of the correct size adapter.

3. Always hold down adapter and plug with one hand when cleaning plugs in Sparkplug Cleaner (blast).

4. Do not hold hood of cleaner (or control valve) in AIR BLAST position or CLEANING BLAST position for more than three seconds at a time. Complete entire cycle (all notches on adapter); then remove plug and examine. If still dirty, repeat procedure, but only as much as necessary to remove deposits.

5. Do not attempt to remove deposits by the use of pick.

6. Brush plug base threads with dry cleaning solvent (Specification P-S-661) after blasting.

Note

Extreme caution should be used in cleaning plugs having mica shielding barrel insulators to prevent solvent from coming in contact with the mica. Keep inside of barrel dry.

CAUSES	REMEDIES
Moisture or oil in distributor.	Clean distributor rotors with dry cleaning solvent (Specification P-S-661), using clean cloth. Wipe clean with dry cloth. Check vent lines and screen for foreign matter.
Magneto incorrectly timed to engine.	Check magneto timing. Refer to page 85.
Dirty, burned, or pitted breaker points.	Clean dirty points. Replace points badly burned or pitted.

Note

Ignition troubles commonly result from neglect in periodical inspection of breaker points, distributor brushes, distributor segments, sparkplugs, terminal connections and condition of batteries.

5–22. FUEL AND INDUCTION SYSTEM. (Rough Running)

CAUSES	REMEDIES
Leaking connections.	Tighten or replace connections.
Carburetor leaking.	Repair external leaks; replace carburetor, if leaking internally. Refer to page 106.
Vapor in fuel system.	Remove vent plug from carburetor, place mixture control in "Rich", and operate booster pump until fuel spurts from vent; then reinstall vent plug.

Note

Vapor lock is the partial or complete interruption of fuel flow due to the presence of air water vapor and fuel vapor in the fuel feed system. The occurrence of vapor lock depends on the fuel characteristics, the pressure drop in the fuel feed system, the vapor handling capacity of the fuel system, and particularly the vapor pressure at the fuel temperature in the tank.

5—22. FUEL AND INDUCTION SYSTEM, Cont'd.

CAUSES	REMEDIES

Some causes of fuel boiling and vapor lock are:

1. At low altitude, vapor lock has occurred due to negative pressure in the fuel tank.
2. The vibration of piping forces air out of solution.
3. Traps in the fuel system.
4. Heat input by pump and engine to fuel.
5. Sharp bends, elbows and large numbers of threaded connections which cause excessive pressure drop in the system.
6. The use of long pipes and small diameter fuel pump suction pipes is most critical, since absolute pressure in them is lowest in the system.
7. Leakage of air into pump section which reduces pumping capacity or loss of prime.
8. When the rate of fuel flow through the pipes is much less than 130 ft./min., vapors and air separate from the fuel at local restrictions and any sharp edges.
9. Rates of flow much higher than 130 ft./min. result in unnecessarily high line loss. At these velocities trouble may also occur from fuel hammering at the time when the throttle is closed.
10. Air may enter the fuel line with the fuel at the tank outlet when the level is low and the fuel agitated. A vortex may also exist at the tank outlet which would draw air into the fuel line.

Some remedies for vapor lock troubles are as follows:

1. Reduce the pressure drop between the tank and the pump.
2. Use an auxiliary booster pump in each tank in addition to engine pump.
3. Supercharge the fuel tank.
4. Use short pipes leading downward from the tank to the strainer and upward from the strainer to the pump.
5. All openings in pumps, valves, tanks and fittings should be of a size equivalent to that of the tubing required and have no abrupt change of area.
6. Eliminate leakage. This may be checked by sealing the tank outlet and maintaining 12 psi suction at the fuel pump inlet.
7. Place a grid or straightening vane in the tank at the fuel outlet.
8. Use combination of moderate tank pressure in addition to the pressure developed by electrically-driven booster pumps in each header tank.

CAUSES	REMEDIES
Clogged carburetor strainer.	Remove and clean strainer.
Improper grade or contaminated fuel.	Drain system and refill; clean strainers.
Air leaks in induction system (blown or leaking gaskets).	Replace gaskets.
Defective pumps (insufficient fuel flow).	Replace defective pumps.
Vibrating flexible fuel lines.	Tighten loose lines. Replace, if necessary.
Carburetor setting and intake scoop not matched.	Replace with recommended parts.
Fluctuating fuel pressure.	Check fuel gage to make sure tanks are full. Check operation of fuel and booster pumps. Repair or replace pumps, if necessary.
Incorrectly adjusted carburetor control linkage.	Adjust linkage so that movement of cockpit controls results in corresponding correct movement of throttle and mixture control levers.
Air leaks or restrictions.	Check air scoop for foreign matter. Check security of carburetor and intake pipe nuts. Check for loose or disconnected primer lines.

5—23. PROPELLER.

(Rough Runnin

CAUSES	REMEDIES
Sludge in the dome.	If the condition is not corrected by moving propeller control from fu INCREASE RPM to full DECREASE RPM several times, with engi running and oil hot, remove propeller dome and clean it out thoroughl

Note

A rough propeller may cause excessive vibration. When this condition is due to the propeller itself, the cause usually lies in the blades and not in the propeller blade operating mechanism.

Scarred or damaged blades.	Visually inspect blades for damage. Repair or replace damaged part
Blades out of track or not all set at same angle.	Check blades for correct tracking. Check blade angle at correct statio Set blades at correct angle.
Loose propeller shaft nut.	Remove propeller and examine all parts for damage. Check engi thrust bearing nut for correct torque. Tighten shaft nut to proper torqu
Malfunctioning engine.	Test engine with propeller assembly of the same type which has bee taken off an airplane that is operating correctly. If roughness still exis after testing with substitute propeller, check engine for proper operatio
Unbalanced propeller.	Replace propeller.
Faulty operation of propeller or governor.	Refer to manufacturer's applicable publications.
Loose or broken engine flexible mounting bracket.	Tighten loose flexible brackets to their proper torque. Replace broke brackets.
Loose exhaust collector ring.	Tighten loose nuts.

5—24. ENGINE.

(Rough Running

Sticking intake valves.	Generally caused by carbon or lack of lubrication. Lubricate stickin valve. Replace cylinder, if necessary. Refer to pages 97 through 101.
Broken valve springs.	Install new springs. Refer to page 103.
Worn or broken piston rings, cracked piston or cylinder head. Burned piston.	Locate by compression test. Replace piston and cylinder assembly. Refe to pages 97 and 98.
Improper valve clearance.	Adjust valves. Refer to pages 81 and 82.

Note

Check the installation of the engine. Check tightness of the mounting bolts and soundness of the mounting lugs.

Loose intake manifold or defective gasket.	Intake manifolds should be checked periodically for looseness.

Note

A loose intake manifold or defective gasket will cause the cylinders to which the manifold is connected to operate unevenly at the lower engine speeds.

Broken cam lobes.	Return engine to overhaul.
Broken tappet roller.	Return engine to overhaul.
Stuck tappet.	Return engine to overhaul.
Broken tappet guide.	Return engine to overhaul.
Broken pushrod.	Replace pushrod. Check valves and valve guides for sticking.
Broken rocker arm.	Replace rockerarm. Inspect valves and pushrods.

APPENDIX I

GOVERNMENT SPECIFICATIONS

A–1. GENERAL.

a. This appendix is included for the purpose of listing specifications of various materials. The table will be used in servicing engines.

b. Products procured under these specifications are acceptable for use by the U.S. Army.

A–2. TABLE OF GOVERNMENT SPECIFICATIONS.

Specification No.	Title	Application (Primary)
MIL-G-5572	Gasoline –Aviation Grade 91/96	
MIL-L-6082	Oil–Lubricating Grade 1100 Grade 1120	Slushing Lubrication Lubrication
MIL-C-14201	Compound–Exterior Corrosion Preventive	External Preservative
MIL-C-6529	Compound–Corrosion Preventive	Engine Interior
MIL-T-5544	Thread Compound –Anti-seize	Threaded Fittings
P-S-661	Solvent; Dry Cleaning	Cleaning
MIL-I-8660	Insulating Compound	Insulating
PPP-T-60	Tape–Adhesive Waterproof	
MIL-B-121	Barrier Material Grease Proofed Flexible (Waterproof)	Covering
VV-K-211	Kerosene	Cleaning
VV-G-109	Gasoline–Unleaded	Cleaning
MIL-D-3464	Desiccant (Activated) in Bags	Storage
MIL-T-7003	Trichloroethylene	Cleaning
MIL-L-3545	Lubricating Grease– High Temperature	Spline or Thread Lubricant

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5—24. ENGINE, Cont'd. (Rough Running)

CAUSES	REMEDIES
Worn rocker arm bearing.	Replace bearing.
Bent valve stem.	Replace valve and/or cylinder assembly. Refer to pages 97 through 101.
Broken pistonpin.	Change cylinder assembly and/or engine.
Broken linkrod.	Return engine to overhaul.
Broken knucklepin.	Return engine to overhaul.
Exhaust port shipping plug not removed.	Remove plug and inspect.

5—25. ENGINE NACELLE. (Rough Running)

Loose air ducts.	Check all air duct connections and supports; tighten where necessary.
Loose cowling supports or exhaust manifolds.	Check and tighten where necessary.
Loose or broken engine mounting brackets.	Replace broken bracket assemblies.
Engine mounting flexible bracket assemblies loose or broken.	Check all core stem nuts and engine mount ring nuts to see that they are tightened to correct torque. Replace any broken bracket assembly.
Loose exhaust collector ring.	Check the exhaust collector ring and tighten nuts, if necessary.

5—26. IGNITION SYSTEM. (Low Power)

Improper spark advance setting.	Check spark advance setting. Refer to page 85.
Defective sparkplugs.	Determine whether front or rear plugs are defective by magneto check. Remove the plugs and replace them with new or reconditioned plugs. Refer to pages 88 and 89.
Defective sparkplug lead connectors.	Clean dirty connectors with a clean dry cloth. Replace damaged connectors. If necessary, dry cleaning solvent (Specification P-S-661) may be used for cleaning. Replace compound as directed on page 89.
Moisture or oil in distributor.	Clean distributor rotors with dry cleaning solvent (Specification P-S-661), using clean cloth. Wipe clean with dry cloth. Check vent lines and screen for foreign matter.
Magneto incorrectly timed to engine.	Check magneto timing. Refer to pages 85 and 86.
Dirty, burned, or pitted breaker points.	Clean dirty points. Replace badly burned or pitted. Refer to page 82.

5—27. FUEL AND INDUCTION SYSTEM. (Low Power)

Insufficient fuel pressure.	To increase pressure, turn adjustment screw on fuel pump to right. See that fuel shut-off valves are operating; observe fuel quantity indicator and check fuel tanks with dipstick; check fuel lines for leaks.
Incorrectly adjusted carburetor control linkage.	Adjust linkage so that movement of cockpit controls results in corresponding correct movement of throttle.
Air leaks or restrictions in induction system.	Check air scoop for foreign matter. Check security for carburetor and intake pipe nuts. Check for loose or disconnected primer lines. Check bypass valve for sticking; check ducts and connections; clean carburetor air filter.
Wrong grade of fuel.	Fill tank with recommended grade of fuel. Refer to page 25.

5–27. FUEL AND INDUCTION SYSTEM, Cont'd. (Low Pow

CAUSES	REMEDIES
Fluctuating fuel pressure.	Check fuel gage to make sure tanks are full. Check operation of f and booster pumps. Repair or replace pumps, if necessary.
Throttle valve does not open fully.	Check rigging of throttle control.
Carburetor air temperature too high.	Check rigging of carburetor preheat control.
Internal carburetor trouble.	Replace carburetor. Refer to page 106.
Dirt and grime on the venturi tubes.	Remove the air screen and clean the venturi surfaces. The characteri of lean metering, due to dirt on the venturis, is especially present at hi airflows such as those encountered during climb and takeoff operati Such a condition may be evidenced by increased cylinder h temperatures.

5–28. PROPELLER. (Low Pow

Note

Propeller malfunctioning is indicated by failure of all engines or of an individual engine, to attain take-off RPM when propeller control is set in full "INCREASE RPM".

Malfunctioning of governor.	Check mounting pad for damaged or wrong mounting pad gasket. If t transfer in the governor will not open, remove the valve and check f dirt. Check governor base plug for incorrect rotation. Inspect drive sh for shearing. Replace governor, if necessary.
Governor high-rpm adjustment improperly set.	Check and correct as necessary.
Incorrect angle setting of blades.	Correct blade setting.
Governor low-rpm stop improperly adjusted.	Adjust and correct.

Note

Sluggish operation is recognized by a slow response of propeller to change in airplane control, airplane attitude, and/or changes in propeller control. When this condition exists, rpm will increase or decrease suddenly, gradually returning to "On Speed".

5–29. ENGINE. (Low Powe

Improper valve clearance.	Adjust valve clearances. Refer to pages 81 and 82.
Sticking valves.	Lubricate sticky valves. Replace cylinder, if necessary. Refer to pages ! through 101.
Broken valve springs.	Install new springs. Refer to page 103.
Worn or sticky piston rings, cracked pistons or cylinder heads.	Locate by compression check. Replace piston and cylinder assembly described on pages 97 through 101.
Leaks or restrictions in exhaust system.	Check for leaking exhaust; check for foreign matter in exhaust syste or cover plate left on exhaust port; adjust or replace any part whic causes leakage; remove foreign matter or cover plate.
Poor compression.	Check for faulty valve or valve action, defective piston rings, or loo sparkplugs.

5—30. ENGINE.

(Loss of Compression)

CAUSES	REMEDIES

Note

The compression which determines the engine power depends upon the proper functioning of the valves. Although it is possible for the engine to lose compression because of leaky compression rings in the piston, low compression for the most part can usually be traced to leaky valves.

CAUSES	REMEDIES
Warped or pitted valve seat.	The extremely high temperatures at which the valve operates sometimes cause the valve head or the stem to become warped. Either condition will prevent the valve from closing tightly. Often when a valve has been burned it will also be found to be warped.
Valve stem covered with scale.	Scaling is the result of burning, although it is mild in form. When this occurs, small flakes form on the valve seat. These are blown away by the exhaust gases causing the valve to become rough and uneven. It is obvious that such a condition destroys perfect compression.

5—31. IGNITION SYSTEM.

(Loss of Power)

Internal trouble with magnetos.	Replace magneto. Refer to pages 91 and 92.
Loose or defective sparkplugs.	Check for defective or fouled sparkplugs, or cracked ceramic insulators; check gap. Replace, if necessary. Refer to pages 88 and 89.
Improper spark advance setting.	Check spark advance setting. Refer to pages 85 and 86.
Defective sparkplug lead connectors.	Apply continuity and high voltage tests to determine if lead is defective. Replace assembly, if defective wires are found.
Magnetos incorrectly timed.	Check magneto timing. Refer to pages 85 and 86.
Dirty, burned, or pitted breaker points.	Clean dirty points. Replace point badly pitted or burned. Check condenser.

5—32. FUEL SYSTEM.

(Loss of Power)

Incorrectly adjusted carburetor control linkage.	Adjust linkage so that movement of cockpit controls results in corresponding correct movement of throttle and mixture control levers.
Internal carburetor trouble.	Replace carburetor. Refer to page 106.
Air leaks or restrictions.	Check air scoop for foreign matter. Check security of carburetor and intake pipe nuts. Check for loose or disconnected primer lines.
Lack of fuel or wrong grade of fuel.	Check fuel gage. Fill tank with recommended fuel. Refer to page 25.
Fluctuating fuel pressure.	Check fuel gage to make sure tanks are full. Check operation of fuel and booster pumps. Repair or replace pumps, if necessary.
Insufficient fuel pressure.	To increase pressure, turn adjustment screw on fuel pump to right; replace pump, if necessary. Refer to pages 97 and 98.

5—32. FUEL SYSTEM, Cont'd.

(Loss of Power)

CAUSES	REMEDIES
	ENGINE (Loss of Power)
Sticking valves.	Lubricate sticking valve. Replace cylinder, if necessary. Refer to pages 97 through 101.
Broken valve springs.	Install new springs.
Worn or broken pistonrings, cracked piston or cylinder head.	Locate compression test. Replace cylinder assembly, if necessary. Refer to pages 97 through 101.
Excess carbon in cylinder head.	Replace piston and cylinder assembly. Refer to pages 97 and 98.

5—33. IGNITION SYSTEM.

(Engine Stops)

WARNING

If an engine cuts out or stops for no apparent reason, the cause may be any of the more common troubles listed in this section. If, however, the engine that has suddenly stopped can be started again and runs normally, every effort should be made before flight to ascertain the reason for the engine's stopping. In such cases, there is grave danger that the trouble, while appearing momentary and of little consequence to the mechanic, may recur later, causing failure in the air.

Short circuit.	Examine all ignition wiring, especially switch wiring on instrument panel and magneto distributor high-tension wires. Look for moisture or corrosion. Check all wires for security even though they appear to be making good contacts.

5—34. FUEL AND INDUCTION SYSTEM.

(Engine Stops)

Out of fuel.	Determine fuel supply both by inspecting gages and checking tanks. Check fuel cocks for "On" position.
Fuel lines obstructed.	A piece of rag or other foreign matter may be floating in the fuel tank to act as a stopper every time it floats by and is sucked against the fuel-supply line. Disconnect gas line at the carburetor to see if gas flow is adequate. Any piping suspected of being even partially obstructed should be removed and blown out with compressed air.
Vapor lock in fuel lines.	See that air vents in gasoline tanks are unobstructed. Fuel lines may be cleared by disconnecting the main supply line at the carburetor and pumping out some of the gasoline.
Carburetor jets restricted.	If possible, jets should be removed carefully and blown out with air pressure. If idling jets are partially restricted, engine will miss or cut out at low rpm. When the trouble is in the main jets, the engine will miss or fail to obtain rpm.

5—35. ENGINE.

(Engine Stops)

Structural failure.	Engine structural failures rarely develop slowly. If it is suspected that internal parts have broken, the engine should be allowed to cool and should then be turned over slowly by hand. Any unusual noise, stiffness, or lack of compression may indicate major internal failure requiring overhaul.

5–36. IGNITION SYSTEM.

(Improper Idling)

CAUSES	*REMEDIES*
Improper spark advance setting.	Check spark advance setting. Refer to pages 85 and 86.
Defective sparkplugs.	Determine whether front or rear plugs are defective by magneto check. If necessary, remove the defective plugs and replace them with new or reconditioned plugs. Refer to pages 88 and 89.
Defective sparkplug lead connectors.	Clean dirty connectors with a clean dry cloth. If necessary, dry cleaning solvent (Specification P-S-661) may be used for cleaning. Replace damaged connectors. Replace compound as directed on page 89.
Moisture or oil in magneto distributor.	Clean distributor rotors with dry cleaning solvent (Specification P-S-661), using clean cloth. Wipe clean with dry cloth. Check vent lines and screen for foreign matter.
Grounded manifold or lead from magneto ground connection to cockpit switch grounded.	Check wiring between ground connection and switch.
Magneto incorrectly timed to engine.	Check magneto timing. Refer to page 85.
Dirty, burned or pitted breaker points.	Clean dirty points. Replace points badly pitted or burned.
Dielectric failure.	Check distributor fingers, covers and bases for carbon tracks or burning. Replace parts as required.
Defective ignition manifold; broken or shorted primary leads; loose connection in distributor block.	Check continuity; replace defective lead or manifold assembly. Tighten connections.

5–37. FUEL AND INDUCTION SYSTEM.

(Improper Idling)

Incorrectly adjusted carburetor control linkage.	Adjust linkage so that movement of cockpit controls results in corresponding movement of throttle and mixture control levers.
Incorrect carburetor idle adjustment.	Adjust carburetor idle mixture. Refer to page 87.
Air leaks or restrictions in induction system.	Check security of ducts, carburetor, and intake pipes; check main air scoop for restrictions; check air induction by-pass valve for operation; replace malfunctioning valve; tighten ducts and remove obstructions. Check for loose or disconnected primer lines.
Excessive fuel pressure.	To decrease pressure, turn adjustment screw on fuel pump to left.
Internal carburetor trouble.	Replace carburetor. Refer to page 106.
Clogged fuel lines.	Locate clogged lines, remove, clean, and reinstall.
Accelerating pump faulty.	Replace carburetor. Refer to page 106.

5–38. PROPELLER.

(Improper Idling)

Propeller not tracking evenly.	Replace propeller.
Propeller out of balance.	Replace propeller.
Sludge in the dome.	If the condition is not corrected by moving propeller control from full INCREASE RPM to full DECREASE RPM several times, with engine running and oil hot, remove propeller dome and clean it out thoroughly.

5—38. PROPELLER, Cont'd. **(Improper Idling)**

CAUSES	*REMEDIES*

Note

A rough propeller may cause excessive vibration. When this condition is due to the propeller itself, the cause usually lies in the blades and not in the propeller blade operating mechanism.

CAUSES	REMEDIES
Scarred or damaged blades.	Visually inspect blades for damage. Repair or replace damaged parts
Blades out of track or not all set at same angle.	Check blades for correct tracking. Check blade angle at correct station Set blades at correct angle.
Loose propeller shaft nut.	Remove propeller and examine all parts for damage. Check engine thrus bearing nut for correct torque. Tighten shaft nut to proper torque.
Malfunctioning engine.	Test engine with propeller assembly of the same type which has beer taken off an airplane that is operating correctly. If roughness still exist after testing with substitute propeller, check engine for proper operation

Note

"Hunting" is defined as a steady oscillation of rpm above a desired speed. "Surging" is an oscillation similar to "hunting," except that its range becomes less with each cycle and finally dies out.

5—39. ENGINE. **(Improper Idling)**

CAUSES	REMEDIES
Improper valve clearances.	Adjust valve clearance. Refer to pages 81 and 82.
Sticking valves.	Lubricate sticking valves. Replace piston and cylinder assembly, if necessary. Refer to pages 97 through 101.
Broken valve springs.	Install new springs. Refer to page 103.
Worn or sticking piston rings, cracked pistons or cylinder heads.	Locate by compression check. Replace piston and cylinder as described on pages 97 through 101.
Cold engine	Allow engine to warm up before attempting to idle engine.

5—40. IGNITION SYSTEM. **(Improper Acceleration)**

CAUSES	REMEDIES
Improper spark advance setting.	Check spark advance setting. Refer to page 85.
Defective sparkplugs.	Determine whether front or rear plugs are defective by magneto check. Remove the plugs and replace them with new or reconstructed plugs. Refer to pages 88 and 89.
Defective sparkplug lead connectors.	Clean dirty connectors with a clean dry cloth. Replace damaged connectors. If necessary, dry cleaning solvent (Specification P-S-661) may be used for cleaning. Replace compound as directed on page 89.
Moisture or oil in magneto and/or distributor.	Clean distributor rotors with dry cleaning solvent (Specification P-S-661) using clean cloth. Wipe clean with dry cloth. Check vent lines and screen for foreign matter. Wipe breaker compartment, block, and bowl with a clean dry cloth.
Ground manifold or lead from magneto ground connection to cockpit switch grounded.	Check wiring between ground connection and switch.
Magneto incorrectly timed to engine.	Check magneto timing. Refer to pages 85 and 86.
Dirty, burned or pitted breaker points.	Clean dirty points. Replace points badly pitted or burned. Refer to page 84.

5—40. IGNITION SYSTEM, Cont'd. (Improper Acceleration)

CAUSES	REMEDIES
Dielectric failure.	Check distributor fingers, covers and bases for carbon tracks. Replace parts as required.
Defective ignition manifold; broken or shorted primary leads; loose connection in distributor block.	Check continuity; replace defective lead or manifold assembly. Tighten connections.

5—41. FUEL AND INDUCTION SYSTEM. (Improper Acceleration)

Incorrect idle adjustment.	Check and adjust idle mixture and idle speed. Refer to page 87.
Insufficient fuel pressure.	Check fuel pressure gage to ensure that pressure drop is not caused by a temporary drop-off owing to increased demand for fuel. Check grade of fuel; fill tank with recommended grade of fuel, if necessary. Refer to page 25.
Malfunctioning fuel boost pump.	Replace fuel boost pump.
Accelerating pump faulty.	Check for disconnected linkage to accelerating pump. If pump is internally defective, replace carburetor.
Fluctuating fuel pressure.	Check fuel gage to make sure tanks are full. Check operation of fuel and booster pumps. Repair or replace pumps, if necessary.
Internal carburetor trouble.	Replace carburetor. Refer to page 106.
Air leaks or restrictions.	Check air scoop for foreign matter. Check security of carburetor and intake pipe nuts.
Mixtures too lean in cruising range.	Engine will not accelerate properly to any given RPM if the mixture at that RPM is too lean for satisfactory operation.
Incorrectly adjusted carburetor control linkage.	Adjust linkage so that movement of cockpit controls results in corresponding movement of throttle and mixture control levers.
Ruptured balance diaphragm in fuel pump.	Replace fuel pump.

5—42. PROPELLER. (Improper Acceleration)

Sludge in the dome.	If the condition is not corrected by moving propeller control from full INCREASE RPM to full DECREASE RPM several times, with engine running and oil hot, remove propeller dome and clean it out thoroughly.

Note

"Hunting" is defined as a steady oscillation of rpm above a desired speed. "Surging" is an oscillation similar to "hunting," except that its range becomes less with each cycle and finally dies out.

5—43. ENGINE. (Improper Acceleration)

Improper valve clearance.	Adjust valve clearance. Refer to page 81 and 82.
Sticking valves.	Lubricate sticking valves. Replace cylinder, if necessary.
Broken valve springs.	Install new springs. Refer to page 103.

5—43. ENGINE, Cont'd. **(Improper Acceleration)**

CAUSES	REMEDIES
Worn or broken piston rings, cracked piston on cylinder head.	Locate by compression test. Replace piston and cylinder assembly, if necessary. Refer to pages 97 through 101.

5—44. FUEL AND INDUCTION SYSTEM. **(Lean Mixture)**

Clogged fuel lines.	Locate clogged lines, remove, clean, and reinstall.
Accelerating pump faulty.	Replace carburetor.
Fuel leaks.	Check lines, connections, joints and clamps.
Internal carburetor trouble.	Replace carburetor. Refer to page 106.
Faulty fuel strainer.	Inspect and clean strainer. Refer to page 105.
Insufficient fuel pressure.	To increase pressure, turn adjustment screw on fuel pump to right; replace pump, if necessary.
Vapor in fuel system.	Remove vent plug from carburetor and operate pump until fuel spurts from vent; then replace plug.
Air leaks or restrictions.	Check air scoop for foreign matter. Check security of carburetor and intake pipe nuts. Check for loose or disconnected primer lines.

5—45. FUEL AND INDUCTION SYSTEM. **(Rich Mixture)**

Accelerating pump faulty.	Replace carburetor.
Excessive fuel pressure.	To decrease pressure, turn adjustment screw on fuel pump to left.
Internal carburetor trouble.	Replace carburetor. Refer to page 106.
Improper jets installed or jets not tight.	Remove carburetor for overhaul.

5—46. LUBRICATION SYSTEM. **(Low Oil Pressure)**

5—47. IMPORTANCE OF PROPER MAINTENANCE FOR ENGINE OPERATION.

No other portion of the power plant system is more vital to the satisfactory operation of the engine than the lubrication system. It should furnish an adequate supply of clean, solid oil to the engine at the proper temperature and pressure for all conditions of operation. A stoppage of oil flow to the engine will result in seizure of the bearings and probably progressive failure in all major parts.

NOMENCLATURE.

1. **"Adequate Supply"** implies ample storage space and minimum restriction to flow.
2. **"Solid Oil"** implies elimination of entrapped air.
3. **"Clean Oil"** implies elimination of solid matter which would be detrimental to the operation of the engine.
4. **"Proper Temperature"** involves temperature regulation which is obtained by the use of a regulating valve and cooling radiators.
5. **"Adequate Pressure"** at the pump inlet is normally obtained by a compensating valve which controls the oil that is by-passed to the engine driven pump inlet.

A separate complete system should be provided for each engine and also a complete independent system for any accessory units or other installation items that require a circulating oil supply.

Note

Oil pressure will change with varying engine speeds and oil temperature. Due allowance, therefore, should be made for pressure drop to be expected at increased temperatures. Engine should be immediately stopped, if no pressure or sudden and unexplained drop in pressure is indicated on pressure gage.

5—47. IMPORTANCE OF PROPER MAINTENANCE FOR ENGINE OPERATION, Cont'd.

CAUSES	*REMEDIES*
Defective oil pressure gage, transmitter or indicator.	Repair or replace gage, transmitter or indicator and source of power.
Diluted, contaminated, or inadequate oil supply.	Drain engine and tank. Refill with lubricating oil (Specification MIL-L-6082, grade 1100) (100 S.U.S. at 210°F.).

Note

Contaminated oil is one of an engine's most dangerous enemies. It fouls piston rings, accelerates carbon formation, changes oil viscosity, and restricts — or even closes — oil lines, leading ultimately to engine failure. It is brought about by the presence of air, moisture, partially burned fuel, soot, fuel dilution, carbon, and other solid contaminants which may form a destructive emulsion when subjected to heat. Once started, its development is malignant. Low manifold pressure, high rpm operation with dirty oil have a deleterious effect on masterod bearings and produce exhaust valve guide wear and high rockerbox temperature.

Obstruction in main oil tank.	Drain oil and clean tank.
Obstruction or leaks in oil lines.	Check oil lines, remove obstructions, and repair leaks. Replace cooler, if necessary.
Clogged main oil strainer.	Remove and clean strainer as directed on page 105.

Note

Periodic cleaning of the oil strainers and an intelligent observance of their accumulations and the condition of the oil as to its contamination are necessary for good maintenance. If the oil is at all gritty, it makes a good material for grinding away surfaces that are rubbing. When the strainers are reinstalled, it is necessary to make certain that they are seated properly. If they are not seated thus, the dirty oil will get by the strainer.

Excessive oil dilution.	Drain oil from engine and oil system. Check operation of oil dilution valve. Inspect valve seat for cleanliness. Replace with lubricating oil (Specification MIL-L-6082, grade 1100)(100 S.U.S. at 210°F.).
Leaking oil dilution valve.	Check oil dilution valve for leaks. Repair or replace, if necessary.

Note

Oil dilution, and particularly over-dilution, loosens a great deal of anchored sludge and puts it into circulation, often to such an extent that oil screens become clogged and cause the oil screen by-pass valve to open, thus supplying the engine with unscreened dirty oil. Leaking oil dilution valves produce the same trouble and may also add spewing to the problems.

Improper operation of oil pressure relief valve.	Remove any foreign material and check seating of valve. Check valve spring. Replace spring of insufficient or excessive pressure or length.
Defective oil pump.	Clean pump and leaking seals. Replace pump, if necessary.
Internal engine trouble.	Check main oil screen and main sump for metal particles. Refer to page 105. Replace engine, if necessary.
Low outside temperature.	In very cold weather the oil may become congealed in the suction line from the oil tank, preventing the oil from reaching the pump in sufficient quantity. Check by lower rpm.
Foaming in oil supply tank.	Foaming oil should be drained and replaced with fresh oil. Drain water from sumps.

Note

Foaming is a frequent cause of fluctuating oil pressure and loss of pressure. While the presence of air in the scavenge line is normal, there should be little or no foam in the supply tank. The return line should be arranged to permit only a minimum of splashing in the tank and allow air which may be trapped to separate from the oil as readily as possible.

5—47. IMPORTANCE OF PROPER MAINTENANCE FOR ENGINE OPERATION Cont'd.

CAUSES	*REMEDIES*
Oil pressure pump not primed.	Disconnect the oil suction line and fill the pump with oil. Air may sometimes become trapped within the pump and relief valve mechanism. Removing and reinstalling the relief valve may eliminate the air lock.
High oil temperature.	With high temperature the viscosity is decreased, causing pressure to drop. Check operation of oil cooler and temperature of oil. A congealed cooler requires closing of the air flow control to thaw out.
Defective oil temperature gage.	Replace oil temperature gage.
Clogged or leaky oil line.	Clean or replace; tighten connections.
Improper operation of oil cooler.	Check flap operation; check thermostat and/or flap actuator.

Note

For proper cleaning of oil coolers the cleaning fluid should be heated to 250°F. for flushing, and not used at room temperature. If used at room temperature, poor viscosity and flushing characteristics will result, with probable deposits of carbon and metal chips.

AC instrument circuit breaker out.	Reset circuit breaker.
Low pressure or head of oil altitude.	Check pressurizing system of oil tank. Check oil level.

CAUTION

It metal particles of appreciable size or quantity are found in the oil-pressure screen or in the main oil sump, the cause must be determined before there is further operation of the engine. If low oil pressure persists despite correction or nonexistence of the above conditions, partial or complete disassembly of the engine may be necessary to detect and rectify the condition. Bushings, bearings, oil seal rings, and shafts should be checked for tightness and fit.

Defective indicator or wiring.	Replace engine gage unit or wiring as necessary.
Cold oil.	Allow engine to warm up.
Automatic oil temperature control unit not operating.	Replace or repair unit.
Oil cooler sludged or clogged.	Clean or replace oil cooler.
Insufficient oil supply (loose hoses).	Tighten or replace connections.
Insufficient oil.	Fill oil tank. Refer to page 25.
Improper venting of oil system.	See that breather and vent in oil tank are open.
Diluted or contaminated oil.	Drain oil from engine and tank and refill with specified oil. Refer to page 25.

5—48. LUBRICATION SYSTEM.

(Total Loss of Oil Pressure)

Obstructions, breaks, or leaks in oil lines.	Check oil lines, remove obstructions, and repair leaks or breaks. Replace cooler, if necessary.
Improper operation of oil pressure relief valve.	Remove any foreign material and check seating of valve. Check valve spring. Replace spring, if necessary.
Defective oil pressure gage, transmitter, or indicator.	Repair or replace gage, transmitter, or indicator.
Defective oil pump.	Clean pump and replace leaking seals. Replace pump, if necessary.

5—48. LUBRICATION SYSTEM, Cont'd. **(Total Loss of Oil Pressure)**

CAUSES	REMEDIES
Diluted, contaminated, or inadequate oil supply.	Drain engine and tank. Refill with recommended oil. Refer to page 25.
Excessive oil dilution.	Check dilution solenoid valve operation. Replace oil in engine and in oil system. If oil dilution solenoid valve leaks, replace.

Note

Foaming of the oil is a frequent cause of fluctuating oil pressure and loss of pressure. Air is normally present in the scavenged oil. The scavenged oil from the engine should be directed into the supply tank in such a manner as to produce a minimum of splashing. Any method to aid in separating the scavenged oil and air is desirable. Lack of proper venting will permit excessive foaming. Examine vent lines. Water in the oil will aggravate foaming. When foaming occurs, the oil should be removed from the system and replaced with fresh oil.

Damaged oil intake lines or gage lines.	Inspect lines and fittings for damage.
Collapsed lines.	Repair or replace lines.
Air lock in take line.	Prime line; preoil engine.
Oil spewing or excessive breathing.	Scavenge pump trouble; excessive blowby due to damaged piston or rings.

5—49. ENGINE. **(Excessive Oil Consumption)**

Worn piston rings.	Return engine for overhaul.
Burned or scored pistons.	Return engine for overhaul.
Defective impeller shaft oil seal.	Return engine for overhaul.
Excessive wear to internal parts of the engine.	Return engine for overhaul.
Loose connections or broken lines.	Replace broken lines and tighten connections.

5–50. SUMMARY: MOST COMMON CAUSES OF TROUBLES.

Engine malfunctioning can in most cases be prevented by a systematic and thorough periodical inspection of those parts which, if neglected, have invariably proved to be recurrent sources of trouble. Below is a summary list of these critical parts for a rapid final check.

IGNITION SYSTEM	FUEL SYSTEM	LUBRICATION SYSTEM	ENGINE AND NACELL
1. Breaker points Dirty Burned Pitted Oily	1. Carburetor Strainer clogged Leaky lines Incorrect idle adjustment Primer solenoid defective	1. Oil Strainer and Sump Metal particles Clogged	1. Valves Improper Clearan Broken Springs Sticking
2. Condenser Shorted Open Burst	2. Accelerating pump	2. Oil Supply Diluted Contaminated Inadequate	2. Piston Rings Worn Sticking
3. Distributor Brushes and Segments Worn Burned Dirty	3. Gages	3. Oil pressure gage	3. Cracked piston
4. Wiring Loose Broken Shorted	4. Pumps	4. Lines and tank Obstruction Leaks	4. Cylinder head Cracked Excessive carbon deposits
5. Loose Connectors		5. Oil Cooler	5. Air ducts Loose
6. Sparkplugs Wet, Fouled Gap Setting Incorrect Insulation (cracked) Gaskets		6. Oil dilution valve	6. Mounting brackets Loose
7. Timing Retarded Advanced			7. Cowling supports Loose
8. Induction Vibrator Defective Unit			

SECTION VI

SERVICE INSPECTION AND ASSOCIATED MAINTENANCE

6–1. GENERAL.

6–2. The work outlined in this section is a normal function of the operating organizations. It consists of periodic inspection, cleaning, servicing, lubricating, adjusting, and such maintenance work as is associated with the routine inspection system.

6–3. The nature and conditions of engine operation determine, to a great extent, the time interval between periodic inspections, which should be in accordance with the intervals established by the operating organization. The allowable interval between inspections should not exceed 60 hours. If an engine is new or has just been overhauled, it should be given a thorough check 15 to 30 hours after installation in the aircraft.

6–4. Army personnel will observe 25, 50, 100, and 200 hour inspections. All periodic inspections shall incorporate the preflight and daily checks.

6–5. PERIODIC INSPECTION SCHEDULE.

NATURE OF INSPECTION	Preflight	Daily	25 Hour	50 Hour	100 Hour	200 Hour	REMARKS
6–6. GENERAL INSPECTION.							
Disconnect battery and ground plane electrically.	✓	✓					
Inspect engine data plate for security of mounting.		✓					
Remove sufficient cowling to inspect engine section for leaks and failure.							After flight.
Inspect engine cowling for security of attachment.		✓					Not excessively tight when engine is cold.
Inspect engine section for oil throwing.		✓					
Inspect engine mount for cracks, tightness, and lockwiring.				✓			

NATURE OF INSPECTION	Preflight	Daily	25 Hour	50 Hour	100 Hour	200 Hour	REMARKS
Inspect cylinder hold down nuts for tightness.				✓			Refer to CAUTION at the end of paragraph 7—70a.
Inspect cylinders for general condition.				✓			Refer to "Cylinder Fin Breakage," page 101.
Inspect deflectors for security and fin clearance.				✓			
Inspect pushrod cover nuts for leakage and lockwiring.			✓				
Check thermocouple leads and connections for tightness.				✓			
Inspect exhaust piping for cracks and signs of burning.			✓				Slip joints should be free, and all connections tight.
Inspect breather screens and clean, if necessary.			✓				
Examine all engine control linkages; remove excess play. Oil joints and bearings, if necessary.			✓				
Inspect for loose nuts and broken lockwiring.			✓				Frequently indicated by signs of oil or fuel leakage.
Inspect accessory pumps for security of mounting.				✓			

NATURE OF INSPECTION	Preflight	Daily	25 Hour	50 Hour	100 Hour	200 Hour	REMARKS
Inspect drain plugs and covers for proper lockwiring.	✓	✓					
Inspect clamps, bonding, rods, and lines.				✓			
Inspect fuel, oil, and pressure gage lines for brittleness.							At engine change. Anneal copper or brass lines that are brittle.
Inspect oil for sludge and carbon.				✓			Sludge and carbon indicate need for oil change.

NATURE OF INSPECTION	Preflight	Daily	25 Hour	50 Hour	100 Hour	200 Hour	REMARKS
6–7. LUBRICATION SYSTEM.							
Remove oil strainer and inspect for metal particles.				✓			After ground runup and again after 10 hours flight time of newly installed engines (new or newly overhauled). Also after every 50-60 hours of flight time. Examine oil strainer for metal particles or other foreign matter. If metal chips are found, they are an indication of trouble within the engine and further investigation should be made to discover their source. In a new installation, the oil system has not always been entirely cleaned of metal particles, and it is not necessarily cause for alarm when particles appear. If nothing wrong can be discovered after foreign matter has been found in the oil strainer, the engine should be given a ground test using new oil. If the quantity of metal chips found after a second ground test is sufficient to warrant removal of the engine, the oil tanks and lines should be thoroughly cleaned and the oil cooler replaced before a new engine is installed.

CAUTION

The introduction of gasoline into the engine oil system tends to loosen carbon and sludge deposits within the system. This carbon and sludge may collect in the engine oil strainer in sufficient quantity to cause the strainer to collapse. Therefore, if gasoline is used to dilute the engine oil during cold weather operation, the engine oil strainer must be removed for inspection and cleaning within an hour or two after the dilution is first used in the season. This inspection and cleaning must be repeated at short intervals until sludge and carbon no longer collect.

When it is necessary to feather a propeller on the ground with the engine *not* running, the oil strainer is to be removed prior to feathering and reinstalled after unfeathering in order to prevent excessive oil pressure resulting from trapped oil above the strainer.

NATURE OF INSPECTION	Preflight	Daily	25 Hour	50 Hour	100 Hour	200 Hour	REMARKS
Change oil	Normally, aircraft engine lubricating oil will be changed only at the time decision is made to extend engine time beyond the basic time, and at engine change except where some unusual circumstance such as duct conditions, failure of minor engine parts, etc., makes it advisable to change the oil before the specified time.						
Inspect oil cooler for security of mounting and for obstructions in the air intake.		✓					
Inspect all oil lines and connections for leaks, dents, cracks, chafing, and security.			✓				
Inspect connections and clamps for general condition, location, and tightness.			✓				If clamps have no take-up left, replace hose conections. Hose clamps should be pulled up snug. Excessive tightening of the clamps destroys the sealing quality of the hose causing oil leaks.
Check to see that drain plugs and cocks are tight and lockwired.		✓					
6–8. IGNITION SYSTEM							
Check ceramic insulation in sparkplugs for chipping or cracks.			✓				**CAUTION** Never disassemble a ceramic plug.
Clean the sparkplugs with a suitable solvent.			✓				
Check sparkplug gap clearance.			✓				Gap = .012" (+ .002" — .001")
Give sparkplugs bomb and leakage tests.			✓				Refer to paragraph 7–45.

NATURE OF INSPECTION	Preflight	Daily	25 Hour	50 Hour	100 Hour	200 Hour	REMARKS
Replace sparkplugs.					✓		
Inspect ignition manifold for loose connections or damaged sparkplug leads.			✓				
Check sparkplug lead connectors for presence of oil, dirt, cracks, or chips.			✓				Remove dirt and oil with dry cleaning solvent (Specification P-S-661).
Check magneto ground wires for security.				✓			
Clean distributor blocks and housing electrodes.				✓			Use a cloth dampened with dry cleaning solvent (Specification P-S-661). Wipe with a dry clean cloth. Allow sufficient time for traces of solvent to evaporate before replacing covers.
Examine all dielectric parts for carbon tracks or for cracks.				✓			
Check sparkplug lead elbow nuts for tightness.				✓			Do not tighten excessively.
Make continuity and high voltage tests of ignition system when distributor covers are removed for any reason.	Apply continuity check to ignition manifold, using low voltage test light or buzzer circuit. Check continuity from distributor block electrode to corresponding sparkplug lead. If an open circuit is found, replace the defective cable. Apply high voltage test to ignition manifold to determine electrical leakage. Use tester Delco Model 724420. This test should be accomplished with a direct current tester imposing no more than 10,000 volts DC on the manifold assembly. The electrical resistivity between leads and from any lead to ground should not be less than 100 megohms and no electrical breakdown should be indicated. Set the tester at 10,000 volts on high resistance. The microammeter should indicate no more than 50 microamperes leakage, and the breakdown indicator should not flash. If excessive leakage is indicated and cannot be eliminated by cleaning distributor block surfaces and sparkplug terminals, replace the defective cable. **Note** If there is an internal leakage in the tester, eliminate it by cleaning insulating surfaces or by other means prior to conducting this test.						
Inspect high tension electrodes for burning.						✓	

NATURE OF INSPECTION	Preflight	Daily	25 Hour	50 Hour	100 Hour	200 Hour	REMARKS
Check starter, generator, and magnetos for security of mounting and condition.		✓					
Inspect breaker points for burning and pitting. Clean around points, if necessary.				✓			
Inspect magnetos for damaged cam followers, oiler felts, and weak springs.				✓			
Check magneto timing.				✓			Refer to paragraph 7–31.
6–9. FUEL AND INDUCTION SYSTEM							
Drain fuel strainers and tank drains. Inspect for presence of water and foreign matter.	✓	✓					
Clean all strainers.		✓					
Inspect carburetor and fuel lines for leaks.		✓					
Inspect fuel line supports and clamps for security, chafing, and looseness.		✓					
Inspect all fuel lines and connections for sharp bends, cracks, leaks, signs of abrasion, or interference with other parts.		✓					
Inspect all shut-off cocks for leakage in open and closed positions.		✓					
Inspect throttle and mixture controls for tightness and lockwiring.		✓					
Inspect carburetor attaching nuts for tightness.			✓				
Inspect carburetor air intake screen. Clean if necessary.			✓				
Check operation of all carburetor controls. Oil moving parts as required.		✓					
Inspect intake pipe nuts for leakage.			✓				

6–10. PRESTARTING INSTRUCTIONS.

6–11. GENERAL. Before engine is started the operator should consult the aircraft manufacturer's handbook for the applicable control position checks and specific ground operating procedures.

6–12. HYDRAULICKING. During periods of idleness, residual oil from the power section will flow toward the lower cylinders, seep past the piston and pistonrings, then accumulate in the lower combustion chambers. Likewise, if the engine is overprimed, excess fuel will flow into the combustion chambers of the lower cylinders, through the inlet valves and intake pipes. With liquid in the combustion chamber, the original compression ratio will be raised causing extremely high pressures to be produced when the piston of a cylinder so affected is moved toward top center of the compression stroke. These pressures may be great enough to damage the cylinder head, piston, or linkrod. In extreme instances the piston may actually "bottom" against the liquid. This condition is known as "hydraulicking" the engine.

6–13. Therefore, it is especially important to pull the propeller through four or five revolutions by hand before starting an engine. If the propeller cannot be reached to be pulled through by hand this function may be performed with the starter. While pulling the engine through by hand or with the starter, the operator must be alert for any sign of the piston being forced against unusually high compression. This will be evidenced by a sudden resistance when being pulled through by hand, or by a sudden slowing down when the starter is engaged. If this condition exists, any further attempt to rotate the crankshaft will result in damage to the engine.

6–14. If liquid lock is suspected, remove the front sparkplugs. Check for the presence of fuel or oil which could have caused the lock. If no liquid is found in any of the cylinders or exhaust pipes, leave the front sparkplugs out, and, with the ignition "Off," crank the engine through, checking to see whether or not liquid is spewed from the sparkplug holes. If there is still no evidence of any condition which could cause hydraulic lock, install the sparkplugs and resume normal starting procedure. If liquid is found in any of the cylinders, remove these cylinders and inspect the linkrods for distortion. This may be checked by placing a straightedge along the sides of the linkrod in two planes giving particular attention to the area in the vicinity of the linkpin hole. Any distortion of the linkrod, however slight, is cause for removal of the engine. If the linkrods are found to be free from damage, inspect the pistons, pistonpins, cylinders, and cylinder flange studs thoroughly for evidence of injury. Stud damage is to be suspected if, when a cylinder is being removed, the flange nuts are found to be loose. If no abnormal condition is noted, the engine may be reassembled and considered satisfactory for further service.

6–15. PERSONNEL. Personnel servicing the aircraft should be cautioned to stand clear when a start is anticipated.

6–16. IGNITION SWITCH. The ignition switch must be in the "OFF" position at all times, except as the actual starting procedure may require.

6–17. CARBURETOR HEAT. Carburetor heat should be in the cold position (OFF).

6–18. CARBURETOR AIR FILTER. Carburetor air filter (where applicable) should be in the unfiltered (OFF) position to prevent damage to these installations in case of backfires.

6–19. COWL FLAPS. It is essential that the cowl flaps be fully open during all ground operation.

6–20. OIL COOLER. The oil cooler shutters should be closed to assist in heating the oil during the warm-up period.

6–21. MIXTURE CONTROL. The mixture control should be in the idle cut-off position until such time as required by the following starting procedure.

6–22. FUEL SUPPLY. The fuel supply valve should not be opened until preparation for starting is made.

6–23. THROTTLE. Consistent starting is dependent to a great extent on the correct positioning of the throttle. With the float type carburetor such as used on R-985 series engines, the carburetor furnishes fuel to the engine only when a definite pressure differential exists between the idle discharge and the fuel in the float chamber. With too great a throttle opening this differential becomes insufficient to produce the necessary flow for complete combustion, resulting, in all probability, in backfiring. A throttle opening such as recommended in the engine starting instructions should provide the proper fuel/air ratio to obtain good starting under various conditions.

6–24. PRIMING. For the initial firing charge, needed to start an engine, fuel must be supplied by the priming system. The priming system introduces atomized fuel into the air contained in the primed cylinders. Under ideal priming conditions a fuel – air mixture of .125 is thus provided. As the starter turns the engine through, more air is introduced into the primed cylinders causing the mixture to be leaned out, but before the F/A ratio reaches the lower limit of combustion, a spark will ignite the mixture and a start is accomplished. The actual amount of priming desirable must be learned by experience, however, the operator may estimate the required amount by observing the following gages: Free Air Temperature (temperature of the air drawn into the engine during starting), Carburetor Air Temperature (temperature of the air in the duct), Oil Temperature (stiffness and temperature of the engine), Cylinder Head Temperature (the amount of heat available in the intake ports to vaporize the prime). Excessive priming will load the cylinders of a cold engine with raw fuel, making the engine difficult to start. Excessive priming also has a tendency to wash the oil off the cylinder walls and may result in barrel scoring or piston seizure. If the engine has been overprimed it is essential that fresh oil be sprayed on the cylinder walls, through the sparkplug holes, before starting. Care should be taken to insure complete circumferential coverage of the cylinder walls. Dry cylinders may be indicated by a squeaking, heard while the engine is being pulled through by hand. Rusting of the piston rings and cylinder walls will occur, if the engine is allowed to stand for a day or more after unsuccessful attempts to start. Underpriming is usually indicated by backfiring of the engine through the intake system, with attendant hazards. When underpriming is suspected, additional priming should be done cautiously.

6–25. USE OF OIL DILUTION SYSTEM. Oil dilution is regulated by an electrically-operated valve which admits fuel at a rate predetermined to meet the requirements of the aircraft involved, when desired, to the oil inlet line of the engine, usually at the "Y" drain valve, thereby reducing the viscosity of the oil in the engine and oil system. Because of substantial differences in the specific gravity and viscosity of gasoline as compared to aviation oil, there is very little tendency for them to mix when introduced into a common line or tank. However, if the two fluids, in any proportion, are forcibly brought together by some type of mechanical agitation, such as that provided by the oil pressure pump, moving internal parts, and the oil scavenge pump, a very permanent mixture is produced. Once the oil and gasoline are thoroughly mixed, diluted oil will not separate, if allowed to stand. Oil dilution installations are usually accompanied by a hopper-type oil tank which increases the effectiveness of the dilution by decreasing the amount of oil in circulation.

6–26. STOPPING. When a cold weather start is anticipated, permit the engine to cool by idling until cylinder temperatures fall below 148°C (300°F), and oil temperatures below 50°C (120°F). If the oil tank needs filling, this should be done prior to starting dilution. With the engine running at approximately 800 to 1000 rpm, hold the oil dilution control in the "On" position for a period varying between 1 and 5 minutes. The proper length of time is dependent upon the expected temperature and the grade and amount of oil in the system and will probably be different for each installation because of different breather arrangements, oil line sizes and oil tank designs. Therefore, it will be necessary for the operator to consult the manufacturer's specific instructions for the aircraft concerned. Only in very extreme weather, that is where temperatures go below 0°F, will there be any necessity for diluting for more than 4 minutes. Under such extreme conditions, dilution of oil in hydromatic propellers is also necessary. This can be accomplished after 3 or 4 minute's dilution by increasing rpm to 1500 or 1600 rpm and moving the propeller control to the high pitch position at least three times. Stop the engine immediately at the end of the dilution period.

6–27. STARTING. A normal cold engine start should be made. Dilution of oil with fuel at the time of the previous stop will permit the starter to turn the engine at a high rate of speed, and no preheating of the oil will be necessary.

6–28. In extremely cold weather adequate dilution will prevent oil cooler or oil line failures due to the high pressure developed by the oil scavenge pump when the engine is started. However, for conservative operation, it is desirable to heat the oil lines, the oil cooler, and accessories at the same time the engine cylinders are being heated.

6–29. WARM-UP. During the warm-up period, the gasoline will be gradually evaporated as the temperature of the oil, engine crankcases, and internal parts increases. With high dilution and extremely cold weather, it will be necessary to make the warm-up at a slightly higher rpm and for a longer period of time than are normally used.

6–30. If oil in the tank or lines is insufficiently diluted, flow to the engine pump will be restricted by the high viscocity of the cold oil. In such cases, it may be noted that oil pressure is unsteady or decreases with an increase in rpm. The oil dilution process should be used during warm-up only if extreme temperature conditions do not permit warm-up in the normal manner. Over-dilution, however, can occur, so that oil pressure must be carefully watched for unusual fluctation or drop-off during the remainder of warm-up, ground test, and the take-off.

CAUTION

If for some reason a flight of at least a half hour's duration is not made after warm-up, some gasoline will remain in the circulating oil or in the oil tank. This is especially true in extremely cold weather. The dilution period should thus be shortened when the engine is shut down.

6–31. FLIGHT. The dilution valve should not be used in flight. A sudden loss or fluctuation of oil pressure or discharge of oil from the breather during flight can be caused by a leaking dilution valve. Momentarily turning the valve on and off may asist in correcting the difficulty. Satisfactory operation will be restored after the gasoline has evaporated from the oil. The dilution valve mechanism should be checked after landing.

6–32. In extremely cold weather and when using long dilution periods before stopping the engine, the gasoline content of the circulating oil may become extremely high, particularly when the caution noted above under "Warm-up" is not observed. Discharge from the breather may occur in this case. Consequently, in extremely cold weather operation, it is advisable to observe carefully the engine breather outlets during, and after, take-off. If a discharge from the breather occurs, it can usually be stopped if engine speed is reduced to 2000 rpm or lower.

CAUTION

The introduction of gasoline into the oil system tends to loosen carbon and sludge deposits within the engine, so the pressure oil strainer should be removed for inspection and cleaning 1 or 2 hours after the dilution system is first used in the season. This inspection and cleaning must be repeated at short intervals until sludge and carbon no longer collect.

6–33. ENGINE STARTING INSTRUCTIONS.

6–34. GENERAL. Ground operation of an engine should not be attempted until the aircraft has first been removed from the hanger. Preparing the engine for flight will include starting, warm-up, ground checks and, in the case of newly installed engines, a complete inspection of the installation after the first run-up. It is recommended that all ground operation be conducted with the engine cowling installed since the overall engine cooling is dependent on the airflow across the engine with cowling installed. While it is possible to maintain cylinder head temperatures within limits at low powers without engine cowling, it is probable that cylinder barrel temperatures will be exceeded due to the reduced airflow. If the barrel temperatures are exceeded the oil film may be destroyed with resultant ring and cylinder barrel damage.

6–35. CONTROL POSITION CHECK.

Ignition	Off
Mixture	Full rich or Automatic Rich
Propeller	Counterweight Type — low rpm (high pitch) Other Controllable Types — high rpm (low pitch)
Carburetor	Cold (Off)
Filtered Air	Unfiltered (Off)
Cowl Flaps	Full Open
Oil Cooler Shutters	Closed
Throttle	1/10 to 1/4 Open

6–36. STARTING PROCEDURE.

a. Note the manifold pressure gage reading before starting the engine as a reference for the power and magneto checks.

b. Pull the propeller through 4 or 5 revolutions by hand. Always pull the propeller through in the direction of engine rotation. Do not back up the propeller as this may force fluid through the intake valves and allow for the possibility of fluid lock when engine is started.

c. Fuel Supply — On.

WARNING

Do not operate the throttle before the engine starts to fire. The fuel thus discharged from the accelerating pump may settle in the air intake, with the possibility of catching fire should the engine backfire as it starts.

d. Auxiliary fuel pump; build up fuel pressure not to exceed 3 psi. Pressure in excess of 3 psi may flood the carburetor.

e. Energize starter (if inertia type).

f. Prime.

Move mixture control to Full Lean or Idle Cut-off.

Move throttle back and forth through its full travel, 0-2 strokes for a warm engine, 3-4 strokes for a cold engine.

Return mixture control to Full Rich or Automatic Rich.

Raise fuel pressure to 3 psi momentarily.

g. Ignition — If using inertia starter, ignition on *Both*; if using direct cranking starter, ignition *Off*; then switch to *Both* after one revolution of the crankshaft.

h. Engage starter (If manually controlled, close booster switch simultaneously).

i. After engine fires, adjust engine speed to 500-600 rpm, watching for oil pressure rise.

CAUTION

If oil pressure does not register on gage almost immediately, STOP engine.

j. Move propeller control to high rpm (low pitch) for 2-position and constant speed propellers (counterweight type).

k. Adjust the heat control to maintain 90°F (32°C) carburetor air temperature.

l. Adjust to 1000 rpm.

m. If a start is not completed almost immediately, reprime and repeat starting procedure.

Note

If the engine does not start after two or three attempts, an investigation should be made to ascertain the cause.

6–37. WARM-UP.

Control Position Check

Mixture	Full rich
Carburetor heat	To maintain 32°C (90°F) carburetor air temperature
Filtered air	As needed
Cowl flaps	Full open
Oil cooler shutters	Closed
Propeller	High rpm (low pitch)
Throttle	1000 rpm

6–38. SPECIFIC GROUND CHECKS.

6–39. The following ground checks must not be made until the oil-in temperature is at least 40°C (100°F). Make the checks with carburetor heat in the cold position.

6–40. IGNITION SAFETY CHECKS.

6–41. Perform this check during warm-up. Switch ignition from *Both* to *Right* and back to *Both*. Switch ignition from *Both* to *Left* and back to *Both*. Switch ignition to *Off* momentarily and back to *Both*.

6—42. A slight drop in rpm when operating on each separate magneto, and complete cutting out at *Off* position indicates proper connection of the ignition leads so that higher powers may be safely imposed.

Note

The following tests must be made with a minimum oil-inlet temperature of at least 40°C (100°F) and with carburetor heat control in cold position.

6—43. PROPELLER GOVERNOR CHECK. Check propeller governor according to propeller manufacturer's recommendations.

CAUTION

Testing of the feathering action of the propeller is not recommended by the propeller manufacturer when the engine is inoperative; but in some installations this test is possible. If the feathering switch is held on after the propeller is completely unfeathered, high pressure oil will be discharged into the engine oil system through the propeller dome pressure relief valve. Since there is no engine oil pressure in the pressure oil strainer chamber when the engine is inoperative, pressure from the feathering pump against the top of pressure oil strainer-assembly may cause the strainer to collapse. Therefore, if feathering action of a hydromatic propeller is tested, remove the pressure oil strainer from the engine before the test is made. When the test is completed, remove the sump drain plug (front sump plug).

6—44. POWER CHECK.

6—45. Open the throttle until the manifold pressure is equal to the field barometric pressure (indicated by the manifold pressure gage reading before the engine is started).

6—46. The rpm obtained should be approximately 2000 rpm, depending on the low pitch setting of the propeller. Variation in altitude of various fields will not change the rpm that will result when opening the throttle to the manifold pressure equal to the field barometric pressure.

6—47. If the approximate rpm cannot be obtained when performing the above check, an investigation should be made to determine the cause for the apparent loss of power.

6—48. MAGNETO CHECK.

6—49. Make magneto checks at manifold pressure equal to field barometric pressure. Switch ignition from *Both* to *Right* and back to *Both*. Switch ignition from *Both* to *Left* and back to *Both*.

6—50. Normal drop-off in either *Right* or *Left* position is 50 to 75 rpm. Maximum drop-off in either *Right* or *Left* position should not exceed 100 rpm. Maximum difference in drop-off between *Right* and *Left* position should not exceed 40 rpm.

6—51. INSTRUMENT READINGS.

6—52. Check oil pressure, oil temperature, fuel pressure and other items at manifold pressure equal to field barometric pressure, propeller in low pitch (high rpm).

6—53. CYLINDER HEAD TEMPERATURE.

6—54. Do not exceed 232°C (450°F) cylinder head temperature during ground operation.

6—55. OIL PRESSURE ADJUSTMENT.

6—56. Desired adjustment at manifold pressure equal to field barometric pressure and with 60°C (140°F) oil inlet temperature .... 75 to 85 psi.

6—57. FUEL PRESSURE ADJUSTMENT.

6—58. Desired fuel pump adjustment at manifold pressure equal to field barometric pressure .... 5 ± 1 psi.

6—59. OIL PRESSURE LIMITS.

	Psi
Minimum at 2300 rpm	70
Maximum at 2300 rpm	90
Minimum at 2000 rpm	60
Desired at 2000 rpm	70
Minimum at 1400 to 1800 rpm	50
Minimum at idle	10

6—60. OIL TEMPERATURE LIMITS.	C°	F°
Minimum for Ground Test	40	104TR
Maximum for Ground Test	85	185
Minimum for take-off and flight	40	104
Maximum, level flight	85	185
Maximum, climb	85	185

6—61. FUEL PRESSURE LIMITS.

Maximum	6
Desired	5
Minimum	4
Idling	2

6—62. CARBURETOR IDLING MIXTURE STRENGTH CHECK (450 rpm). Move the mixture control *slowly toward Idle Cut-off*, manually adjusting to obtain best power mixture. Observe the rise or fall in rpm and/or manifold pressure. This should occur at a point approximately ⅔ to ¾ of the quadrant travel from the Rich position. Read instruments. Move the control back into Rich position before the engine stops. If the idling adjustment is properly set at the recommended rpm, there will be an increase of not more than 10 rpm, and a corresponding drop as the control is moved back to Rich.

6—63. This check should be made in relatively still air and with cylinder head temperatures at stabilized idling temperature. A strong wind or abnormal cylinder head temperatures affect the rpm change. Refer to paragraph 7—32 for specific adjustment instructions.

6—64. ENGINE EQUIPMENT OR ACCESSORIES CHECK.

6—65. Consult the Airplane Manufacturer's Handbook for instructions.

6—66. STOPPING.

6—67. If a cold weather start is anticipated, refer to paragraph 6—25 for a general description of the system, and to the airplane manufacturer's instructions for the specific dilution procedure to be used.

a. Idle until cylinder head temperature is less than 204°C.

b. If Hamilton Standard counterweight propeller is used, shift propeller control to low rpm.

c. Move mixture control to idle cut-off or full lean.

d. When engine stops, turn ignition off.

e. Turn fuel selector off.

6—68. After stopping, leave cowl flaps wide open for 15 minutes. If idle cut-off or full-lean does not stop engine:

a. Close throttle.

b. Turn ignition off.

c. Slowly open throttle.

SECTION VII

ADJUSTMENT, REPLACEMENT, AND MINOR REPAIR

7—1. GENERAL.

7—2. The work outlined in this section can be performed without the facilities usually available at major overhaul activities.

7—3. These instructions are written with the understanding that all lockwiring, cotterpins, palnuts, nuts, washers, bolts, and screws will be removed where necessary in disassembly procedures and that new gaskets, packings, cotterpins, and lockwire will be installed at assembly. Fiber insert nuts and palnuts may be continued in service as long as they are free from mutilation and provide an effective lock.

7—4. The surfaces of all engine parts which are subject to friction should be coated with oil or other suitable lubricants prior to their assembly to the engine.

7—5. Care should be taken to prevent dirt, dust, or other foreign matter from entering the engine. Suitable plugs and coverings should be used over all openings in the engine.

7—6. When other engine parts interfere with the removal of a single part, the procedure for removing them can be found under their individual headings in the following text. For information about other interfering parts peculiar to the particular installation, the applicable aircraft manufacturers' handbook should be consulted.

7—7. Refer to Section VIII for a numerically charted tool list, and to paragraph 7—110 for the torque recommendations required in servicing the R-985 engine.

7—8. LOCKWIRING.

7—9. PRELIMINARY INFORMATION.

7—10. This section, outlining the fundamental principles and practical application of lockwiring, has been prepared for the guidance of personnel responsible for the assembling and overhauling of these engines. Because of the many theories existing as to how lockwire should be installed, it is believed that a standardized procedure, incorporating the best methods, is desirable. The methods chosen were selected for their efficiency and ease of installation.

7—11. Lockwiring is the most positive and satisfactory method of securing in place the various bolts, nuts, cap screws, and studs which hold together the parts of an engine and which cannot otherwise be satisfactorily locked. Generally speaking, lockwiring is the tying together of two or more parts in such a manner that any tendency of any one part to loosen will automatically be encountered by the tightening of the wire. Cotterpins are usually associated with castellated nuts; however, if the castellated nut is used on a stud, a cotterpin would secure the nut to the stud, but would not prevent the stud from backing out of the housing. In a case such as this, the lockwire will act as a cotterpin and if the wire is then attached to an adjacent part, the stud also will be held securely in place.

7—12. There are many combinations of lockwiring with certain basic rules common to all. These rules can be outlined as follows:

a. *Lockwire Must Always Tend to Tighten.* The wire must be installed in such a way that it will always counteract any tendency of the part to loosen. In other words, it must always tend to tighten and keep the part locked in place.

b. *Lockwire Must Never Be Overstressed.* Extreme care must be exercised when twisting the wires together to insure that wires are securely tightened, but not stressed, to the point where they will break under a slight load.

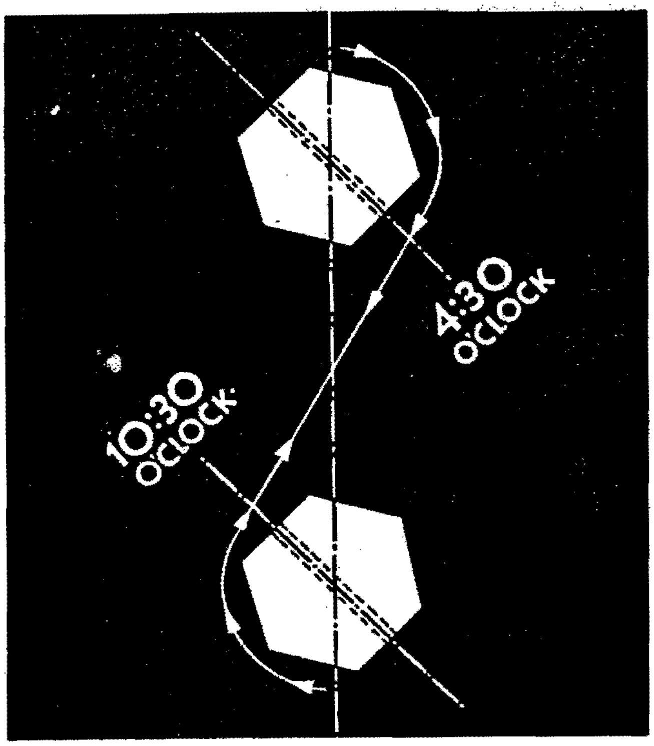


Figure 7—1. O'Clock Positions

c. *Lockwire Must Be Tight When Installed.* That is most important to prevent vibration with resultant fatigue and failure, and also to prevent the wire from rubbing against some adjacent part, causing wear.

d. *Lockwire Ends Must Always Be Bent Toward The Engine.* This is primarily a safety precaution to guard against possible injury to the hands of the mechanics working on the engine. It is also imperative that the part or parts to he lockwired are torqued to specifications and the holes properly aligned before any attempt is made to proceed with the lockwiring.

7—13. HOLE ALIGNMENT. Check the units to be lockwired to make sure that they have been correctly torqued and that the wiring holes are properly positioned in relation to each other. When there are two units, the hole in the first unit should be between the three and the six o'clock positions and the hole in the second unit between the nine and twelve o'clock positions *[Figure 7—1]*. Positioning the holes in this manner insures that the wiring will have a positive locking effect on the two units, since the braid will always exert a tightening pull on both units. Never over torque or loosen units to obtain proper alignment of the holes. It should be possible to align the wiring holes when the units are torqued within the specified limits. However, if it is impossible to obtain a proper alignment of the holes without either over or under torquing, another unit should be selected which will permit proper alignment within the specified torque limits.

7—14. LOCKWIRING PROCEDURE. Bolts will be used for the purpose of describing the folowing general wiring procedure:

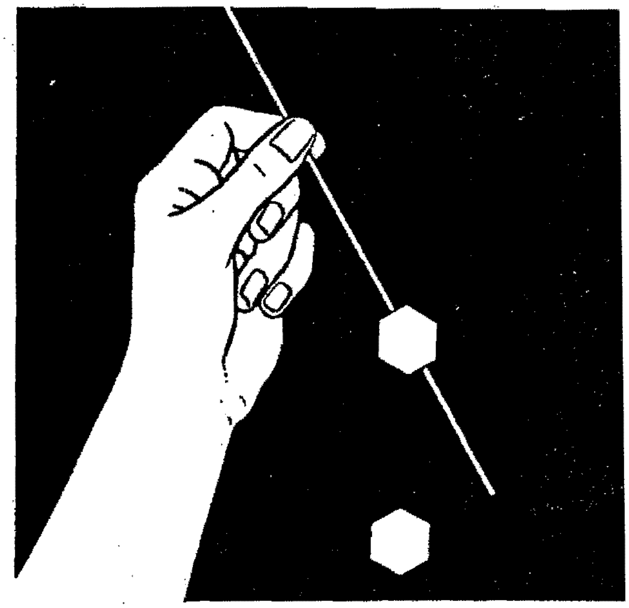


Figure 7—2. Inserting Wire

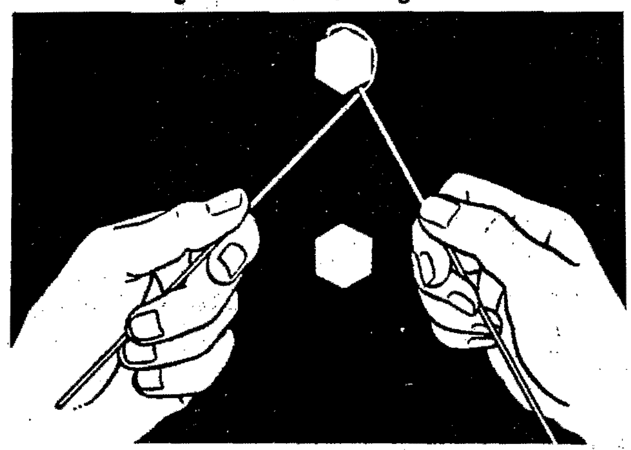


Figure 7—3. Position of Wire After Bending

a. Insert wire of the proper gage through the hole which lies between the three and the six o'clock positions on the bolt head *[Figure 7—2]*.

Note

To determine the proper wire to be used in conjunction with a particular tightening operation, refer to the Engine Parts Catalog, in which the part number of the wire is located with the number of the part which locks.

b. Grasp the left end of the wire the fingers and bend it clockwise around the head of the bolt and under the other end of the wire *[Figure 7—3]*.

c. Pull the loop very tight all around the head of the bolt with the pliers. Grasp the wire only at the end in order not to mutilate any portion which is to be twisted. Holding the wire ends apart and keeping the loop tight around the head of the first bolt, twist the wires around each other in a clockwise direction to form the braid.

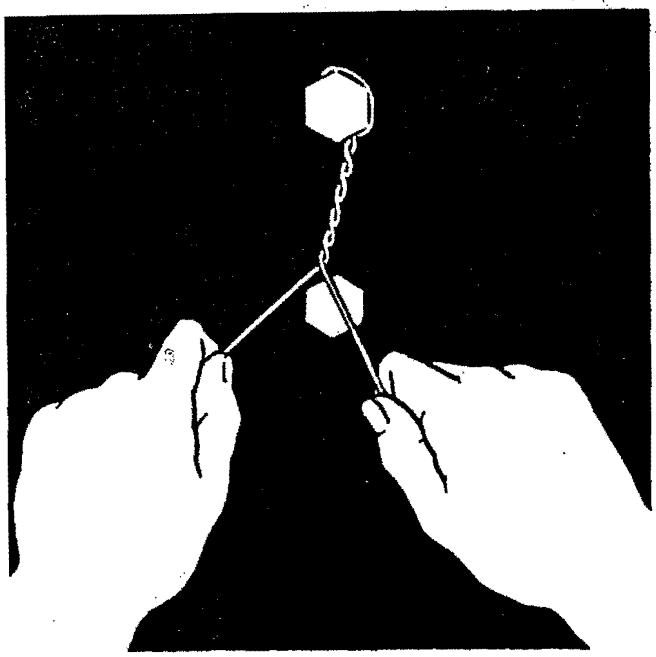


Figure 7–4. Twisting Wire

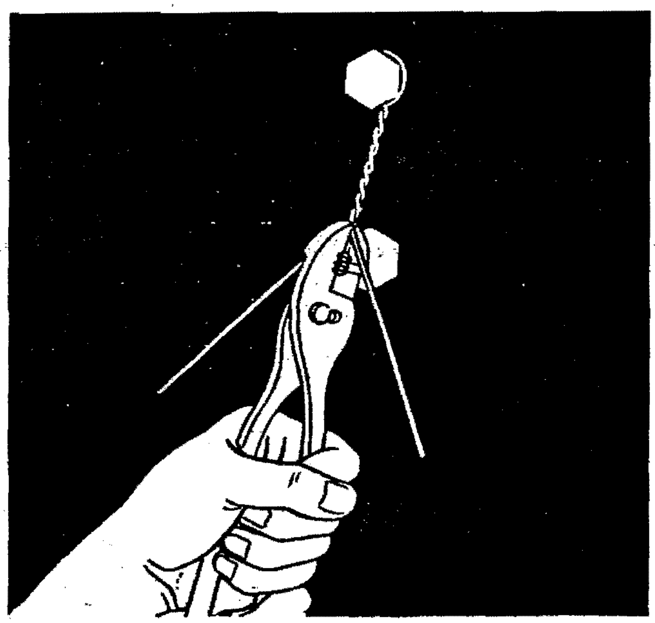


Figure 7–5. Wire Braided

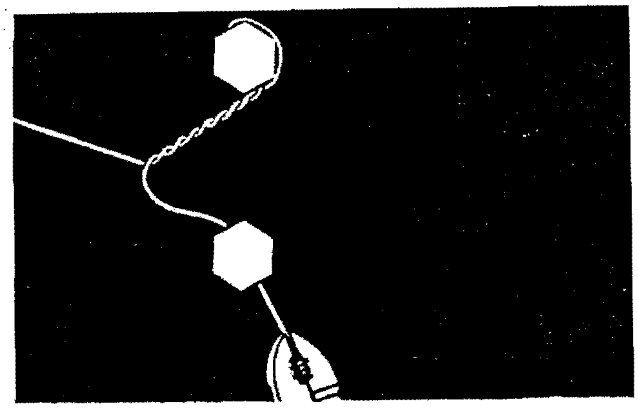


Figure 7–6. Pulling Braid Taut

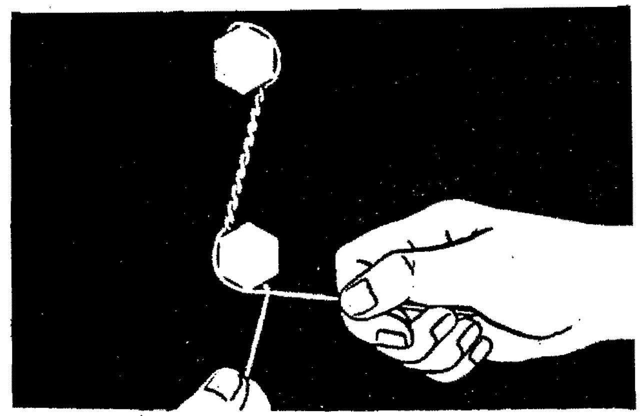


Figure 7–7. Second Bolt Secure

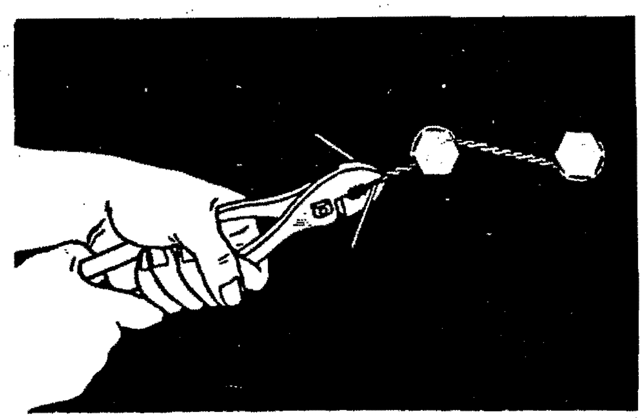


Figure 7–8. Twisting Wire Ends

Continue twisting the wires by hand toward the second bolt until the end of the braid is just short of the second bolt's hole which lies between the nine and the twelve o'clock position *[Figure 7–4]*.

d. Make sure that the loop around the head of the first bolt is still tight and in place; then grasp the wires in the jaws of the pliers just beyond the end of the braid and, with the braid held taut, twist in a clockwise direction until the braid is stiff *[Figure 7–5]*.

Note

Twisting the braid in a clockwise direction has the effect of securing the loop down around the head of the first bolt. The rigidity of the stiff braid reduces vibration and resultant wear. Do not overstree the wires by attempting to twist the braid too tightly.

e. After making sure that the braid is not too long that it cannot be pulled taut between the bolts, insert the end of the wire which is on top through the hole between the nine and the twelve o'clock positions on the second bolt head. Grasp the end of this wire with the pliers and pull braid taut *[Figure 7–6]*.

f. Bring the other end of the wire counterclockwise around the head of the second bolt and under the wire end which protrudes from the bolt hole *[Figure 7–7]*.

g. Pull the resulting loop tight with the pliers; then

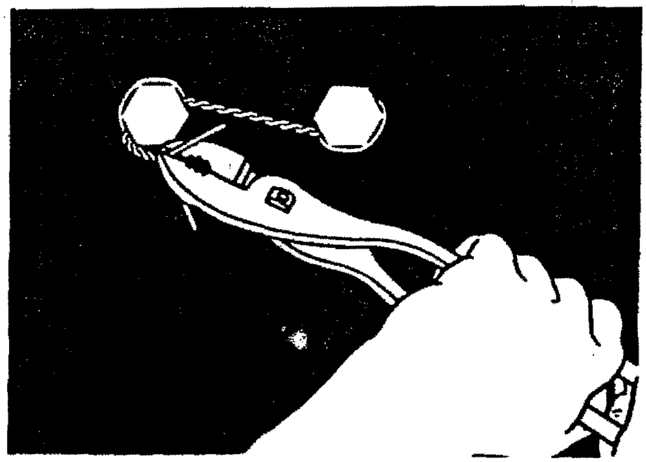


Figure 7—9. Ends Twisted

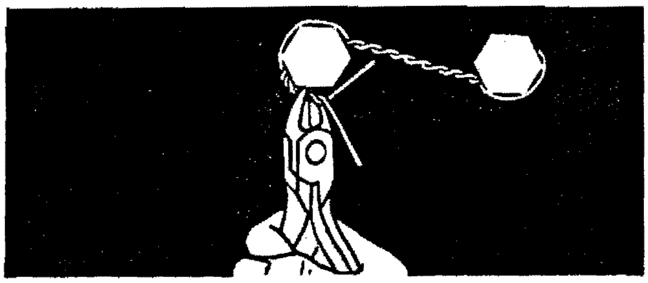


Figure 7—10. Cutting Excess Wire

to keep the wire in place down around the head of the second bolt, twist the wire ends together in a counterclockwise direction *[Figure 7—8]*.

h. Grasping the ends of the wire beyond the twist with the pliers and keeping the wires under tension, twist them tight in a counterclockwise direction. With the final twisting motion of the pliers, bend the twisted wire ends to the right around the head of second bolt *[Figure 7—9]*.

i. Cut off the excess wire at the ends with diagonal cutters, leaving at least three full twists and avoiding sharp or projecting ends *[Figure 7—10]*.

CAUTION

Do not twist off the ends of the wires with pliers.

7—15. BASIC TYPES OF LOCKWIRING. Many separate wiring operations are required, most of which are covered by the seven basic examples illustrated in *Figure 7—11*.

7—16. Examples 1 and 5 illustrate the proper method of wiring bolts, fillister head screws, square head plugs, and similar parts which are wired in pairs.

7—17. Example 2 illustrates the proper method of wiring a bolt or similar part of a castle or slotted nut.

7—18. Example 3 shows how to wire three or more units together. Note that the braid between the second and third units should be twisted counterclockwise so that the wire from the hole in the second unit will be on top of the loop around the second unit to hold it down in place. The wire inserted in the lockwire hole in the third unit should be the lower wire of the braid and beyond the third unit this wire should be brought over the other wire to secure the loop in place arond the head of the third unit.

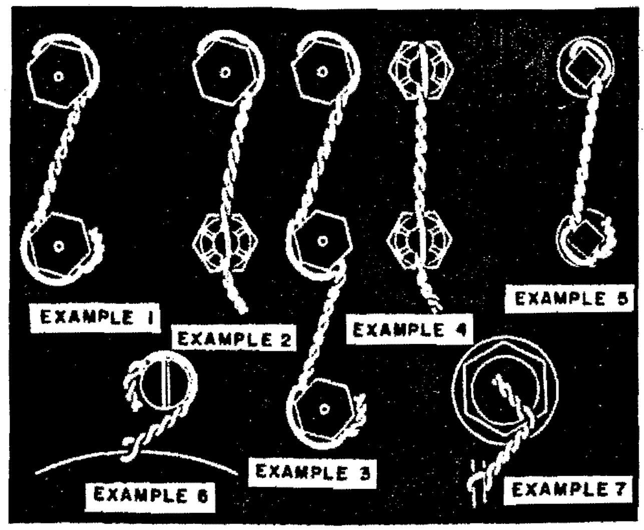


Figure 7—11. Seven Basic Examples

7—19. Example 4 illustrates the proper method of wiring studs and castle nuts together.

7—20. Examples 6 and 7 illustrate the proper method of wiring a screw or a plug to a fixed point, such as a lug.

7—21. CHECKS AND ADJUSTMENTS.

7—22. ADJUSTMENT OF VALVE CLEARANCES. Adjustment of valve clearances is usually not necessary during normal periods between overhauls. If an adjustment should become necessary, however, perform the work when the engine is cool.

a. Remove the rockerbox covers and the front sparkplugs of all cylinders.

b. Adjust the valves in the order of cylinder firing (1-3-5-7-9-2-4-6-8). Rotate the crankshaft, in the normal direction of rotation until the desired piston is at top

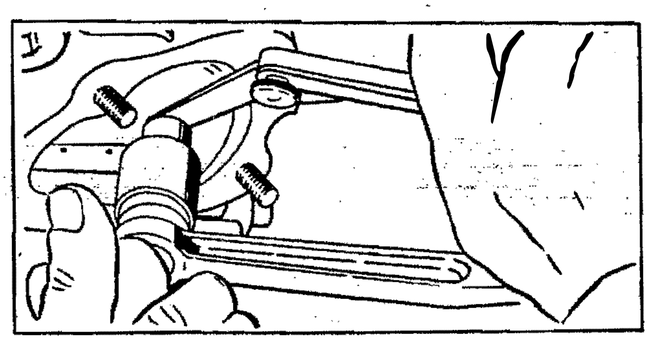


Figure 7—12. Checking Valve Adjustment

dead center of its compression stroke (both valves closed).

c. Loosen the adjusting screw locknut three or four turns. Insert the .010 inch feeler of R41-G-415 Gage between the valve stem and the adjusting screw insert *[Figure 7—12]*. Using PWA-4152 Driver, set the adjusting screw so that there is a slight drag on the feeler gage. Lock the screw in this position by tightening the locknut to the recommended torque.

d. Not more than six threads (1/4 in.) or fewer than three threads (1/8 in.) of a valve adjusting screw should show above the locknut; and there should be a clearance of not less than .031 inch between the outer valve spring washer and the rocker with the valve just starting to open. If the clearance between the valve spring washer and the rocker is less than .031 inch or if more than six threads on the adjusting screw show above the locknut, the flat face of one or both of the pushrod ballend spacers may be ground, or the spacer can be replaced with a thinner one or eliminated entirely to obtain the desired clearance. If fewer than one and one-half threads of the adjusting screw show above the locknut, a thicker spacer should be used at one or both ends of the pushrod. Make all other valve clearance adjustments in the same manner; then turn the propeller shaft in the normal direction of rotation two revolutions, and recheck the clearance of the valves which were adjusted.

CAUTION

Changing pushrod length to obtain correct adjustment, should be made only when it is assured that no other discrepancies exist in the valve gear train.

e. Install the rockerbox covers and gaskets. Install new gaskets, otherwise serious oil leakage may result. Tighten the rockerbox cover nuts to the recommended torque.

7—23. IGNITION SYSTEM *[Figure 7—13]*. Ignition is furnished either by two Bosch or two Scintilla magnetos, located at the rear of the engine. The magnetos seldom need attention between overhauls. Under normal conditions, the wear or burning of the breaker points offsets the wear of the cam follower. However, a faulty condenser or the presence of oil or grease on the points may cause excessive burning of the points. Lack of lubrication may lead to excessive wear of the cam follower. If the wear at one of these locations exceeds the wear at the other, a change in spark timing will result. If ignition trouble occurs and the sparkplugs, leads, and connector are examined and found to be in good condition, the breaker points should be replaced with a new or reconditioned set and checked for proper timing and synchronization.

7—24. BREAKER POINT INSPECTION. If the breaker point surfaces are fouled with oil or dirt, or are burned excessively *[Figure 7—14]* replacement of the complete breaker assembly is recommended. In an emergency when no replacement parts are available, a fouled assembly can be made serviceable for temporary use by removing it from the magneto and washing the point surfaces carefully using dry cleaning solvent (Specification P-S-661) or clean unleaded gasoline (Specification VV-G-109) as a cleaning agent. When this is done, the cleaning agent must be allowed to completely evaporate before placing the assembly back in service.

CAUTION

When inspecting the breaker points, do not raise the breaker main spring beyond a point giving 1/16 inch clearance between the points. Any further tension on the spring will weaken it and adversely affect the performance of the magneto.

7—25. SCINTILLA MAGNETOS. After the assembly has thoroughly dried, check the cam follower felt for the proper amount of oil by squeezing the felt tightly between the thumb and forefinger. If the fingers are moistened with oil when this is done, the felt is adequately lubricated and NO more oil should be applied. If no oil is left on the fingers, the follower felt is too dry and should be oiled as follows: Apply one drop of S. A. E. No. 60 Aircraft engine oil to the bottom felt pad, and one drop to the upper felt pad. Allow at least 15 minutes for the felt to absorb the oil; then blot off any excess oil with a clean cloth. Reinstall the assembly in the magneto and secure it with the two locking screws. The breaker points must now be checked for proper adjustment (timing and synchronizing).

7—26. BOSCH MAGNETOS. No manual lubrication of the cam follower should be required between major overhaul periods. The distributor gear shaft is partially hollow, with the space thus provided acting as an oil reservoir. When the oil reaches the surface of the gear shaft it travels through a small hole in the cam to the surface where it lubricates the contact area between the cam and follower block.

7—27. If the breaker points are unfit for further service, the complete breaker point assembly should be replaced, unless the special tools required to install the breaker points to the breaker plates are available.

7—28. REMOVAL OF BREAKER PLATE ASSEMBLY.

a. Remove breaker cover.

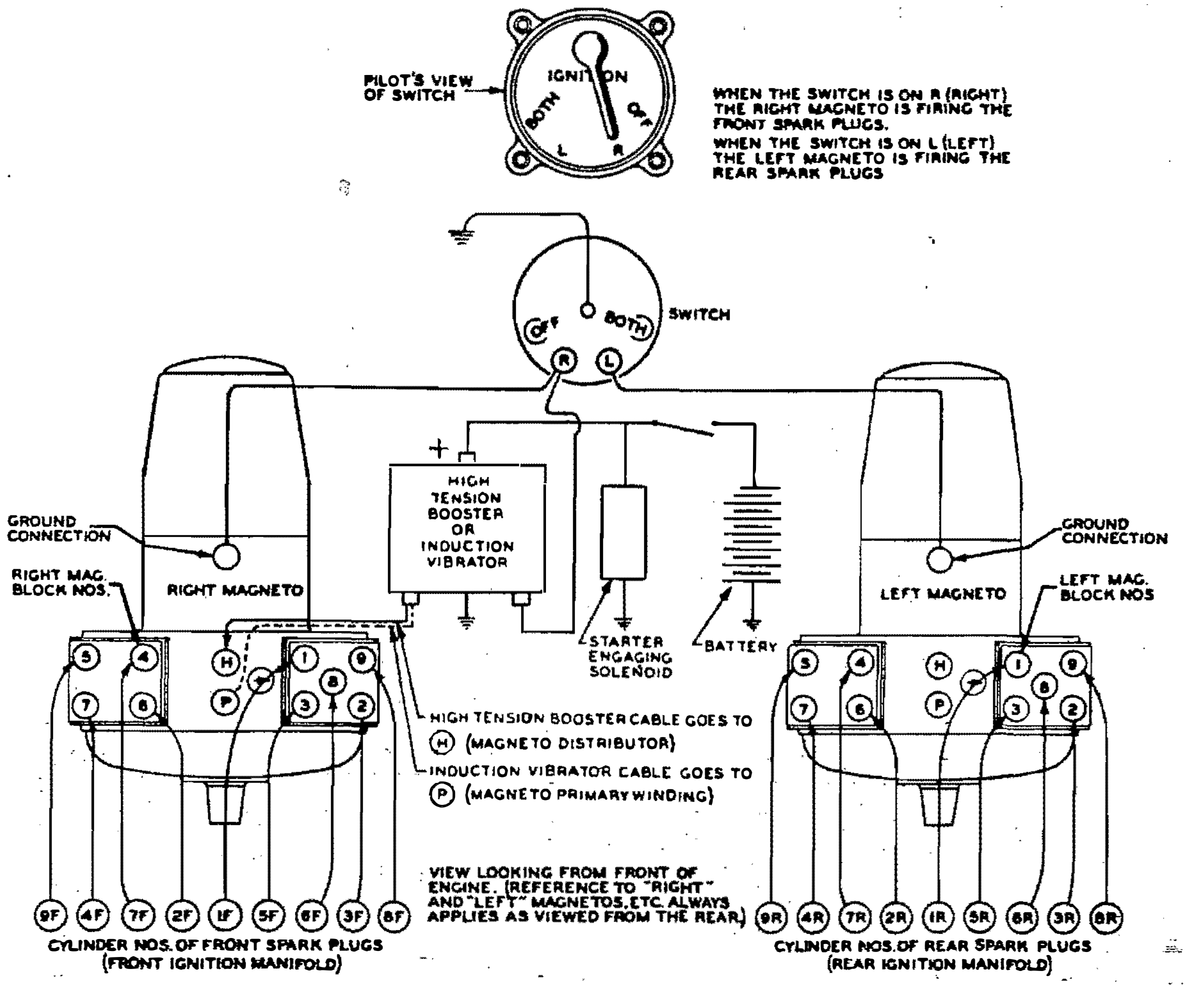
b. Remove the 3/4" hexagon nut.

c. Remove the timing collar and copper sealing gasket.

d. Disconnect the primary lead.

e. Remove the three fastening screws which secure the breaker assembly to the gear housing. The entire breaker assembly can now be removed.

f. Withdraw the breaker cam, key, and copper washer from the distributor gear shaft.



MAG. BLOCK NO.	1	2	3	4	5	6	7	8	9
CYLINDER NO.	1	3	5	7	9	2	4	6	8

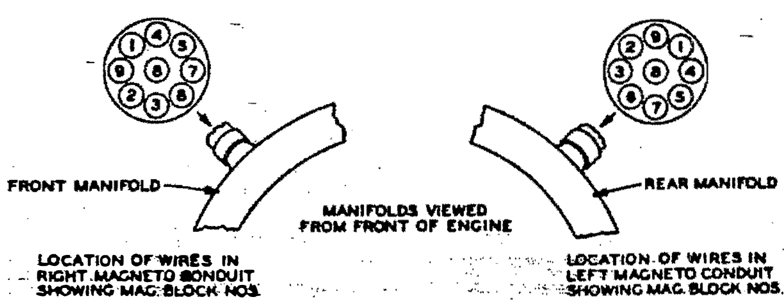


Figure 7—13. Ignition System

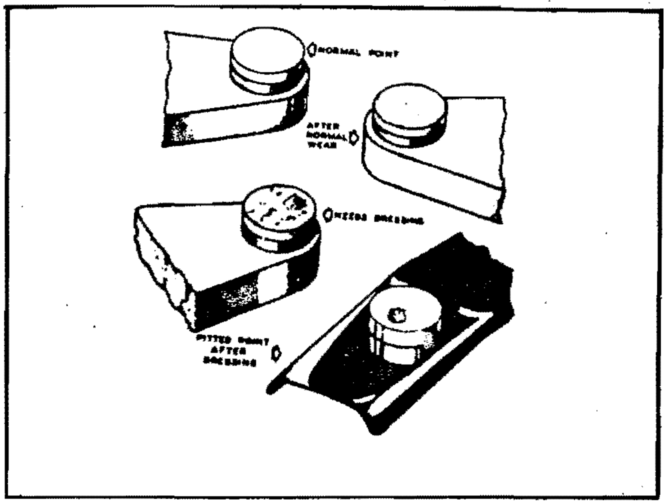


Figure 7–14. Breaker Point Conditions

7–29. INSTALLATION OF BREAKER PLATE ASSEMBLY.

a. Fish primary lead from breaker assembly through hole in gear housing assembly.

b. Mount the breaker plate assembly to the gear housing, with the three fastening screws, lockwashers and plain washers, finger tight.

c. Slide the copper washer over the distributor gear shaft, until it rests against the bearing.

d. Mount the cam with woodruff key and copper gasket on shaft.

e. Assemble timing collar which fits into cam slots in one position only, by pressing it into place by hand until it seats in the slots.

f. Install and tighten hexagon nut.

g. Secure the primary lead.

h. Turn the propeller shaft and locate firing position as described in paragraph 7–31. At this setting the breaker points should be starting to open. Place a straight edge across the step of timing collar *[Figure 7–15]*; it it must line up with timing marks "T" on rim or gear housing. If this is not the case, loosen the three fastening screws and turn the entire breaker plate in its slots until the marks do line up, the then tighten the three screws firmly. Check the breaker point setting at this time by inserting a .009 feeler blade between the points. Jar the propeller shaft in the direction of rotation until cam follower is on the highest point of No. 1 lobe. The feeler should just become free. If feeler blade indicate that the breaker point opening is other than .009 to .010, then adjust by loosening screw and moving contact bracket with point, slightly by means of eccentrically-leaded stud, until correct opening is obtained. Tighten screw firmly after the adjustment has been made.

7–30. BREAKER POINT ADJUSTMENT.

a. Do not change the adjustment of the breaker points unless the following check indicates the necessity.

b. Remove the front sparkplugs from all cylinders and install PWA-3252 Vent Plugs in the sparkplug holes. Turn the crankshaft, until the piston of No. 1 cylinder is at the top center of its compression stroke. Remove the breaker compartment covers of the magneto.

c. Attach the red wires of PWA-2417 Timing Indicator to the breaker points of the magneto and ground the black wire to the engine. Turn the ignition switch in the cockpit to the "Both" position.

d. Turn the crankshaft opposite the normal direction of rotation approximately 90 degrees; then turn it in the normal direction until the lights of the indicator just flash on. As the lights flash on, the cam of the magneto should be just beginning to open the breaker points, and a straightedge should align with 1/32 inch of the timing mark on the magneto housing. If the straightedge is not within the 1/32 inch alignment, adjust the breaker points as follows.

e. With the magneto cam in its proper position to open the breaker points – that is, with the straightedge aligned with the timing mark on the magneto housing, loosen the contact bracket screws on Scintilla magnetos or, if Bosch magnetos are installed, loosen the breaker plate screws. Turn the eccentric adjusting screw until the indicator light just flashes on, indicating that the points are opening. Tighten the screws.

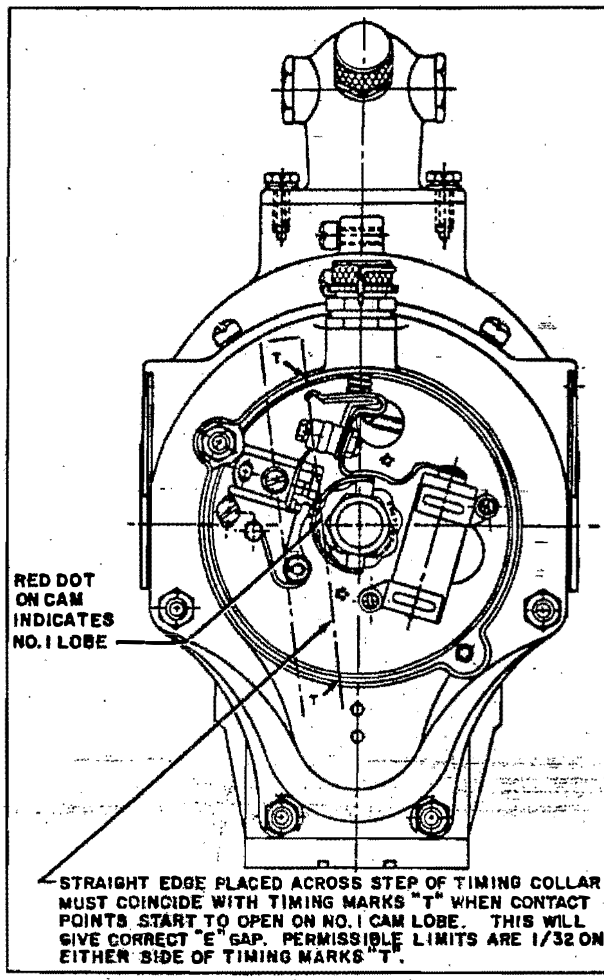


Figure 7–15. Checking Bosch Magneto

f. Check the setting of the points by turning the crankshaft approximately 90 degrees opposite the normal direction of rotation and turning the crankshaft back until the indicator light just flashes on. At this point the straightedge should line up within 1/32 inch of the timing marks on the magneto housing. If the points cannot be adjusted so that the straightedge will align within 1/32 inch of the timing marks, replace the breaker assembly. Turn the ignition switch in the cockpit to the "Off" position. Remove the timing indicator from the magneto. Install the breaker compartment cover.

7–31. TIMING AND SYNCHRONIZING MAGNETOS.

a. To determine whether the magnetos are properly timed to the engine and synchronized with each other, the following check should be made.

b. Remove the front sparkplugs from all the cylinders and install PWA-3252 Vent Plugs. Locate the compression stroke of No. 1 cylinder by either of the following methods: [1]Hold finger over sparkplug hole and turn propeller in normal direction of rotation until compression stroke is noted; or [2] Remove the rockerbox covers from the No. 1 cylinder and turn the propeller shaft in the normal direction of rotation until the piston is at the top of its stroke as determined with the aid of the end of a pencil or a length of wood dowel. Move the propeller back and forward and note whether the valves of the cylinder are actuated. If the exhaust and inlet valves of the cylinder are not actuated, the cylinder is on its compression stroke. If either or both valves are actuated, turn the propeller until the desired condition is obtained. Install R85-I-4075 Indicator (Time-Rite) in the top sparkplug hole of No. 1 cylinder *[Figure 7–16]*.

CAUTION

Use pivot arm "A" of R85-I-4075 Indicator with the hook end up.

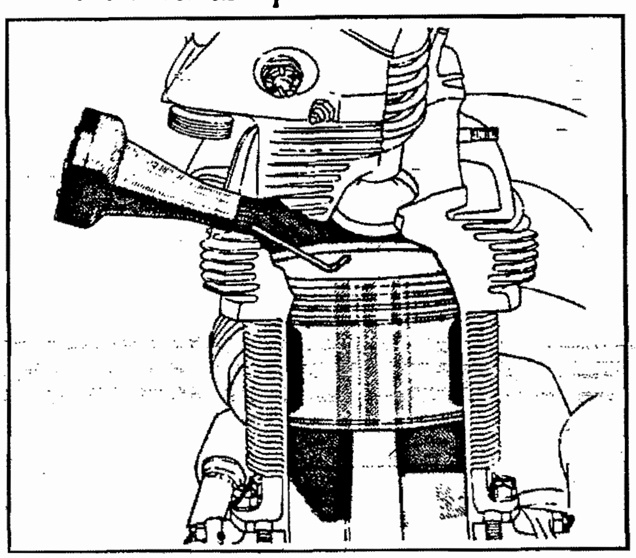


Figure 7–16. Time Rite Installed

c. Attach the red wires of PWA-2417 Indicator to the breaker points of the magnetos and ground the black wire to the engine. Turn the ignition switch in the cockpit to the "Both" position. Align the cap of R85-I-4075 Indicator so that the slide slot lines up with the vertical axis of the cylinder and the scale is at the right of the slot. Push the slide pointer up close to the pivot arm *[Figure 7–17]*. Turn the crankshaft in the normal direction of rotation until the pivot arm pushes the slide pointer to its farthest point *[Figure 7–18]*. Turn the crankshaft 90 degrees opposite rotation to return the pivot arm to the top of the slot. Adjust the proper engine scale (the scale is marked R-985) so that the zero degree mark on the scale aligns with the reference mark on the

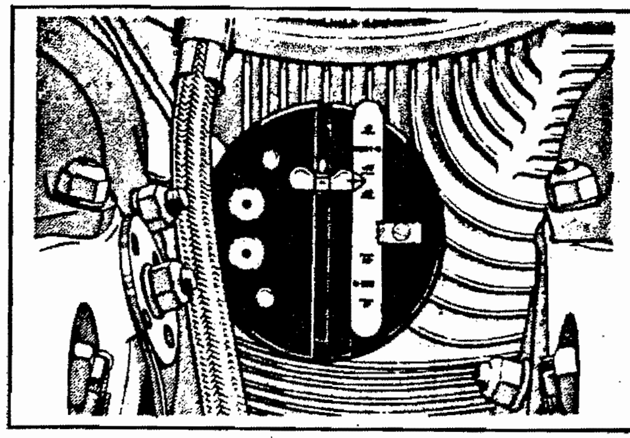


Figure 7–17. Slide Close To Pivot Arm

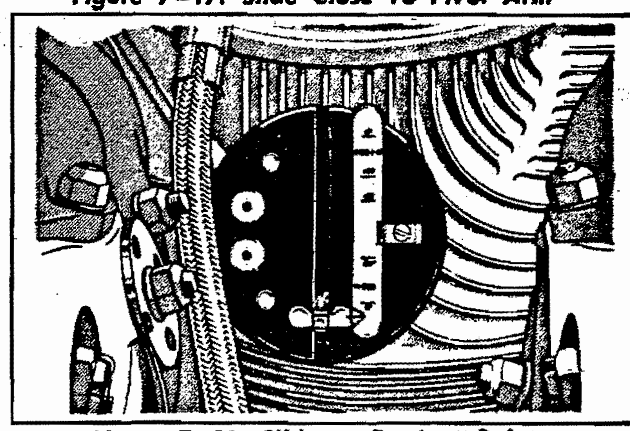


Figure 7–18. Slide at Farthest Point

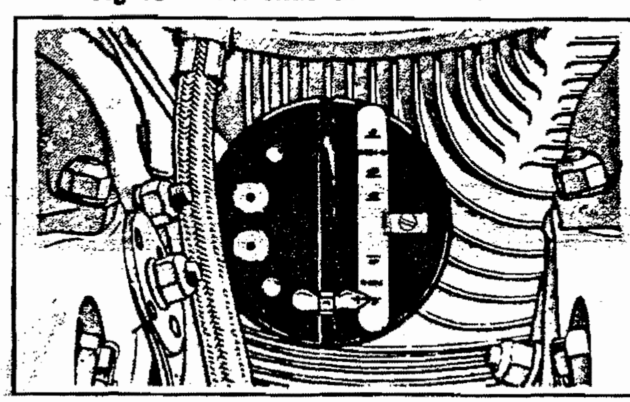


Figure 7–19. 0° Aligned with Slide

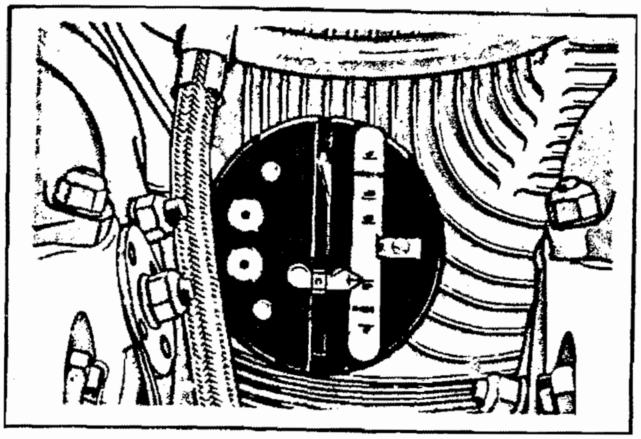


Figure 7–20. Slide at 25° Mark

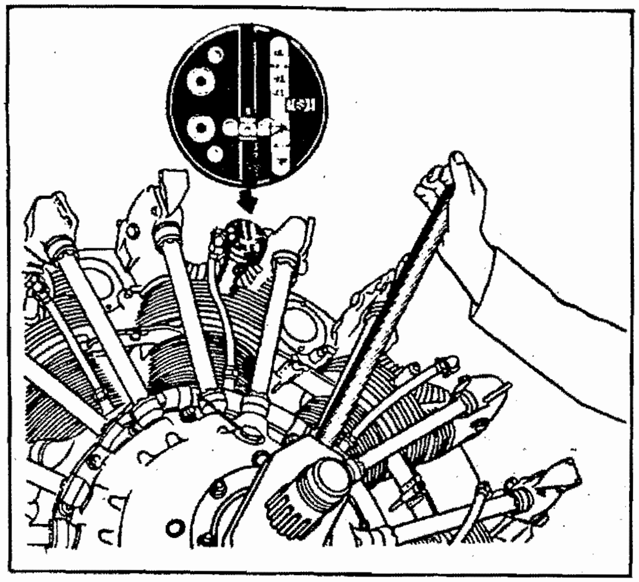


Figure 7–21. Pivot Arm Contacts Slide

slide pointer *[Figure 7–19]*. Move the slide pointer up to align with the 25 degree mark on the scale *[Figure 7–20]*. Turn the crankshaft until the pivot arm just contacts the side, at which time the lower light in R85-I-4075 Indicator flashes on *[Figure 7–21]*. The No. 1 piston is now 25 degrees before top center.

Note

In timing engines that are not installed, the spark advance mark under the thrust bearing cover plate, rather than R85-I-4075 Indicator, may be used. This requires removing the thrust bearing cover plate and the use of PWA-85 Timing Pointer *[Figure 7–22]*.

d. At this point the lights of PWA-2417 Indicator should flash on simultaneously, indicating that the points are just opening. Check the alignment of the timing marks with a straightedge. This will give the correct "E" gap. Permissible limits are 1/32 inch on either side of the timing marks. An adjustment, described in the following paragraph, will be necessary if the magnetos are not synchronized. When the piston is 25 degrees

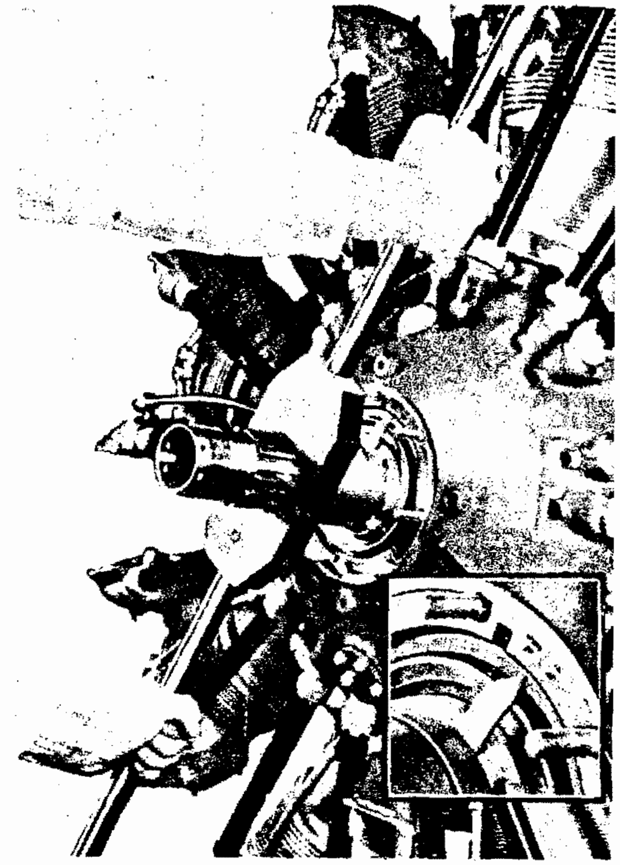


Figure 7–22. Propeller Removed

before top center, the breaker points should brea simultaneously if the straightedge is in correct relatio ship to the timing marks. If the magnetos are found t be properly synchronized after the above check is mad turn the ignition switch in the cockpit to the "Off" p sition and restore the engine to its condition prior t this check.

e. If the timing of one or both magnetos to th engine is incorrect. it will be necessary to remove th bolts which attach the incorrectly timed magneto to i mounting pad and move the magneto away sufficientl to turn the rubber drive coupling. Make sure the pisto of No. 1 cylinder is 25 degrees before top center. If it i desired to advance the timing, the rubber couplin should be turned one or two notches in a counterclocl wise direction, the magneto reinstalled in place, and th timing rechecked as described above. To retard the tin ing, the rubber coupling must be turned in a clockwis direction. Because of the fact that the coupling has 1 notches on one side and 20 notches on the other side, very fine adjustment can be made by rotating it on notch. It is important that the two magnetos be syr chronized to break simultaneosly with the straightedg or timing indicator in correct relationship to the mark on the breaker housing. Slide the magneto back int position, install the bolts and recheck the magneto tin ing and synchronization.

7–32. CARBURETOR IDLING ADJUSTMENT. Idling and taxiing present special conditions. The fuel-air ratio must be held within narrow limits: to prevent the sparkplugs from fouling because of excessive richness, on the one hand, and, on the other, to avoid any tendency to "die" or accelerate hesitatingly because of overleanness. Properly set idle mixtures will make possible continuous smooth idling without danger of fouling. When a carburetor is once set for proper idling, it does not ordinarily require adjustment except to correct it for wide variations in weather conditions. An idling adjustment should not be changed until all other possible causes of unsatisfactory idling have been investigated. Use the following procedure when necessary.

a. Start the engine and run it approximately 1000 rpm until the oil temperature reaches 60°C to 70°C (140°F to 158°F) and the cylinder head temperatures are normal.

b. Run the engine up to recommended rpm and check the sparkplugs by operating on each magneto separately. Refer to paragraph 6–48. If the drop-off in rpm is normal, proceed with the idling adjustment.

c. Slow down to closed throttle, 450 to 500 rpm. Adjust the throttle stop if the engine does not idle at approximately this rpm.

d. Move the mixture control slowly toward Idle Cut-Off, manually adjusting to obtain best power mixture. Observe the rise or fall in rpm and/or manifold pressure. This should occur at a point approximately 2/3 to 3/4 of the quadrant travel from the Full Rich position. Read instruments. Move the control back into Full Rich before the engine stops. If the idling speed adjustment is properly set at the recommended rpm, there will be a rise not in excess of 10 rpm as the mixture is leaned out, and a corresponding drop as the control is moved back to Full Rich.

e. If the engine rpm decreased when the mixture control was moved toward Idle Cut-Off, turn the idle mixture adjustment lever one or two notches to the left (counterclockwise) to richen the mixture and again check the rpm when the control is moved toward the Idle Cut-Off position. Repeat until about 10 RPM rise is obtained.

f. If the engine rpm increased by more than 10 rpm when the mixture control was moved toward Idle Cut-Off position, turn the idle mixture adjustment lever one or two notches to the right (clockwise) to lean the mixture; then again move the mixture control towards Idle Cut-Off and check the rpm.

g. It is desirable to maintain cylinder head temperatures which will approximate the coolest stable temperatures encountered at idling rpm under the atmospheric conditions of operation.

h. The 10 rpm enrichment is needed to aid in cold starting when the engine has a tendency to backfire and not to be so rich as to foul sparkplugs under warm operation. Tendencies of the engine to foul plugs or to torch are indications of idle adjustment being too rich. Tendencies to backfire under very cold starting can be alleviated by richening the idle two or more notches before starting and resetting after the engine is up to idling temperatures.

7–33. FUEL PRESSURE ADJUSTMENT. If it is necessary to adjust the fuel pressure, loosen the locknut of the fuel pump pressure relief valve and turn the adjusting screw *clockwise to increase* the fuel pressure, or *counterclockwise to decrease* the pressure. When the locknut is tightened it may change the discharge pressure slightly, so it is advisable to take this condition into account when the adjustment is being made. Make certain the locknut is tightened and lockwired after the adjustment has been made.

7–34. FUEL PRESSURE CHECK (At manifold pressure equal to field barometric pressure.) Fuel pressure should be 5 ± 1 psi. Idling – 2 psi Minimum.

7–35. OIL PRESSURE ADJUSTMENT. Remove the adjusting screw acorn cap, on the oil pressure relief valve, using PWA-978 Wrench *(Figure 7–23)*. Loosen the locknut and turn the adjusting screw clockwise to increase the oil pressure, or counterclockwise to decrease the pressure.

Adjust to give an oil pressure of 70 psi at an oil temperature of 60°C (140°F), and an engine speed that results from operating at a manifold pressure equal to field barometric pressure. It may be necessary to make several tries before the desired pressure is obtained.

Tighten the adjusting screw locknut; then, using a new gasket, install, tighten, and lockwire the acorn cap.

7–36. OIL PRESSURE CHECK.

(At manifold pressure equal to field barometric pressure.)

Desired for adjustment 70 psi at 60°C (140°F).

SAFE OPERATING RANGE.

2000-2200 rpm	60-100 psi
1600 rpm	55-90 psi
1400 rpm	Minimum 50 psi
Idling	Minimum 10 psi

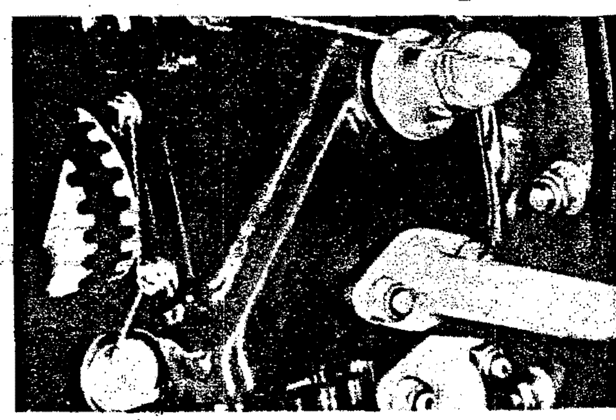


Figure 7–23. Relief Valve

7–37. REPLACEMENT, INSPECTION, AND REPAIR.

7–38. REMOVAL OF COWLING. Remove sufficient cowling to have easy accessibility during the removal of any parts.

7–39. INSTALLATION OF COWLING. Install the cowling sections that were removed.

7–40. REMOVAL OF EXHAUST PIPING. Unfasten the nuts and bolts which fasten the exhaust piping to the engine. Loosen the exhaust manifold and pull it back as far as possible so that the cylinders and related parts will be more accessible.

7–41. INSTALLATION OF EXHAUST PIPING. Move the exhaust manifold inward and fasten the exhaust collector to the engine with nuts and bolts.

7–42. REMOVAL OF SPARKPLUG LEAD CONNECTORS AND SPARKPLUGS. Unfasten the sparkplug lead from the sparkplug, using PWA-1683 Wrench [*Figure 7–24*]. Be careful not to allow the elbow to turn or the wrench to slip; then unscrew the nut which secures the sparkplug elbow. Withdraw the ceramic connector from the sparkplug pulling the lead straight out and in line with the center line of the sparkplug barrel; then install a suitable protector cap over it [*Figure 7–25*]. Remove the sparkplug, using PWA-3168 Wrench. Do not "cock" the wrench on the sparkplug; make certain that the "hex" of the wrench is in full engagement with the "hex" on the plug [*Figure 7–26*]. Install a PWA-3252 Plug in the sparkplug hole. If the plug is difficult to remove, removal may be facilitated in some cases by turning the plug first in a tightening direction and then in a loosening direction.

7–43. Inspect the firing end of the plug(s) that was removed. If there are any signs of cracked or broken insulators, or bent or melted electrodes, it is recommended that an inspection of the cylinder be made for signs of operational damage to the piston and combustion chamber. The cylinder inspection should be made by (1) removal of the cylinder, (2) inspection of the piston through the sparkplug hole and inspection of the valves by means of a compression check.

7–44. Place removed plugs in a suitable rack or tray. If a plug has been dropped or damaged during removal, tag it for future reference.

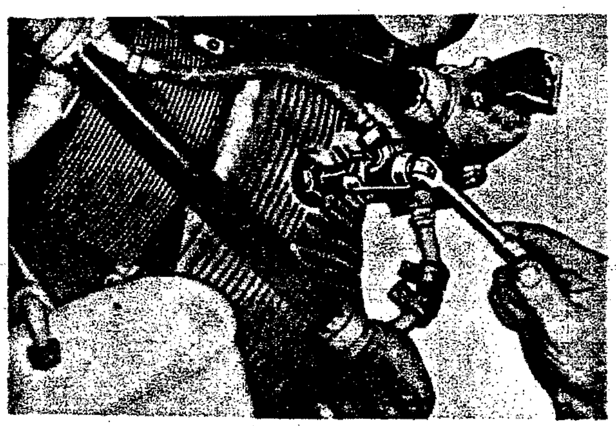


Figure 7–24. Unfasten Sparkplug Lead

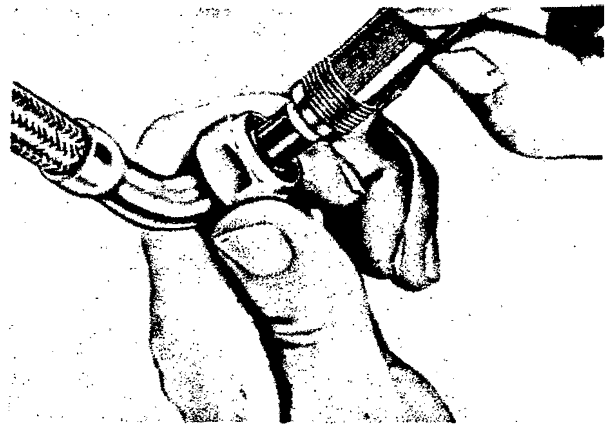


Figure 7–25. Install Lead Protector

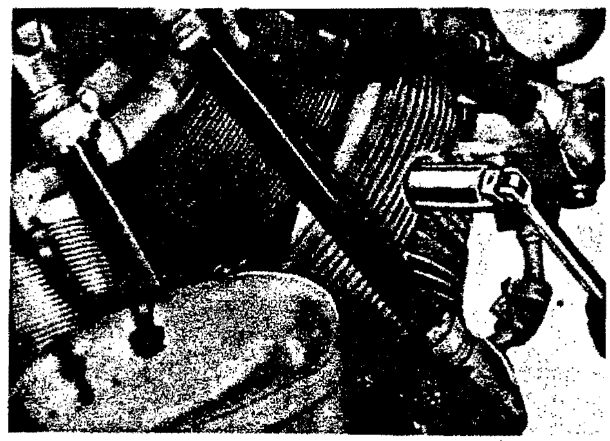


Figure 7–26. Remove Sparkplug

7–45. PREPARATION OF SPARKPLUGS FOR INSTALLATION. Remove sparkplugs from boxes and place in a rack for vapor degreasing [*Figure 7–27*].

a. Vapor degrease, using trichloroethylene (Specification MIL-T-7003), or equivalent for 1 to 3 minutes (a longer period will do no harm). Vapor degreasing serves two functions: (1) removes preservative and cleans plugs, (2) removes any accumulated moisture.

WARNING

Avoid prolonged breathing of trichloroethylene vapors and prolonged or repeated contact with skin. Observe fire precautions.

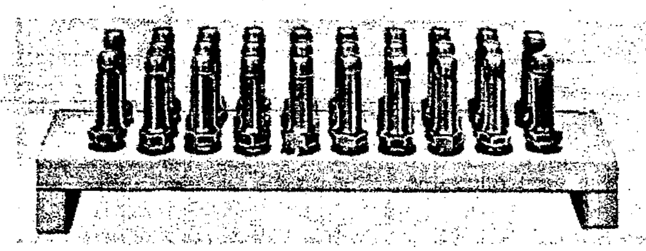


Figure 7–27. Sparkplugs in Rack

b. Remove plugs from trichloroethylene and inspect visually. Use a strong light to inspect the firing end of the ceramic insulator and barrel insulation for cracks, dirt, or lead compound accumulation. Observe the condition of the electrodes and inspect for mutilation of threads at the shell and barrel ends of the plug.

c. Check gap clearance of each electrode with .011 inch "go" and .014 inch "no go" stainless steel piano wire. (Use Starrett pin vise as holder for wire and "roll" wire between the electrodes.) Do not attempt to push it through as an inaccurate gauge will result. The wire will easily "roll" through electrodes of some plugs, whereas the same wire cannot be pushed through. The desired gap is .012 inch; however, if .011 inch gauge will pass through the electrodes but .014 inch gauge will not, the gap clearance is satisfactory. Where a plug is found to be closed below the lower limits, no attempt should be made to disassemble the plug or to open the gaps to the specified clearances. Instead, return such plugs to the sparkplug overhaul shop.

d. Bomb check plugs on a BG M519 tester, or equivalent, at 200 psi. Observe the spark to make certain that it occurs at the electrodes and is steady. The plug should be rejected if there is failure to fire steadily at 200 psi, or if there is any indication of firing below the electrodes.

7-46. INSTALLATION OF SPARKPLUGS AND SPARKPLUG LEADS. Visually inspect plugs prior to installation. Check firing end of ceramic insulator for cracks, dirt and gap setting. Observe the condition of electrodes and inspect for mutilation of threads at shell and barrel ends of plug. Never install a plug that has been dropped.

a. Apply anti-seize thread compound (Specification MIL-T-5544) sparingly as a thin film on the shell threads, taking special care to coat the first several threads. Make sure that the compound is thoroughly mixed because, after settling, the finely powdered mica or graphite separates from the compound and collects in the bottom of the container. A small brush should be used to apply the compound [*Figure 7-28*]. Do not apply with the fingers.

b. Visually inspect the condition of the sparkplug insert or bushing and make certain that the top of the sparkplug hole is clean and smooth.

c. Making certain that there is a serviceable copper gasket (only one) on the sparkplug, screw the plug into the cylinder with the fingers until the plug bottoms on the gasket. If the plug does not screw in easily, remove the plug and inspect the plug and bushing threads.

d. Minor imperfections of sparkplug threads should be corrected, where possible, by using a small three-cornered file. Avoid use of die since the threads may be cut too deeply to permit a tight fit of the plug in the bushing. If a die must be used, it should be used by hand without a die holding handle. The die should be checked periodically to be certain it cuts a pitch diameter within the limits 0.6693 to 0.6683 inch.

e. Stainless steel sparkplug inserts or bushings may be cleaned with a stiff fiber or wire brush moistened with a dry cleaning solvent (Specification P-S-661). The brush may be used so that no bristles will fall into the combustion chamber. The diameter of the brush and the technique used should be such as to preclude the re-

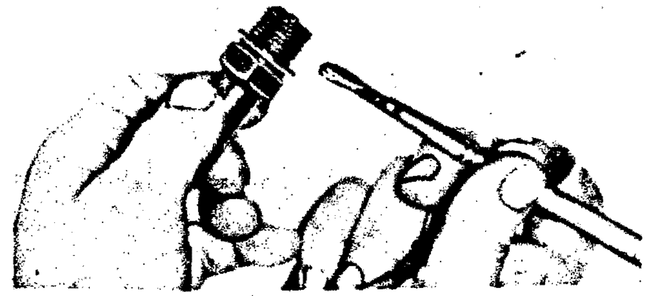


Figure 7-28. Compound to Sparkplug

moval of materials from the cylinder head surrounding the insert. Special care should be taken on the sparkplug gasket seating surface, since removing material from this location could cause combustion leakage with subsequent damage to the cylinder head. Generally speaking, only a light application of a revolving brush will be required.

f. Using PWA-3168 Wrench, tighten the sparkplug to the recommended torque. Avoid side loading or "cocking" of the wrench.

g. Remove the plastic protector from the sparkplug lead connectors.

h. Wipe hands dry, wipe the connector clean with a clean cloth moistened with dry cleaning solvent (Specification P-S-661), or equivalent.

CAUTION

Never use chlorinated solvents, Alcohol, or Acetone.

i. Visually inspect the connector and spring. Do not touch with fingers. If necessary, replace the spring or insulator and wipe them clean.

j. If desired, apply a light film of insulating compound (Specification MIL-I-8660) to the connector by means of a clean cloth [*Figure 7-29*].

WARNING

The insulating compound contains minutely ground silica and mica which may act as irritants to the eyes and skin. When compound is handled frequently, it is suggested that gloves be worn.

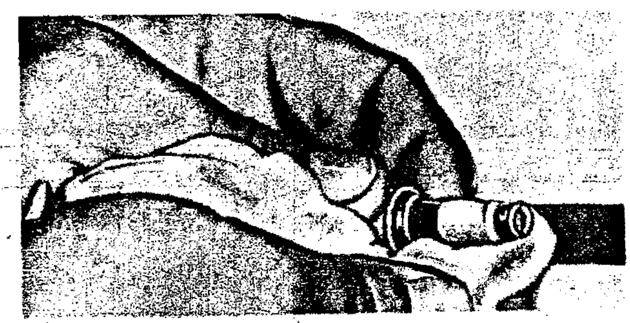


Figure 7-29. Compound to Connector

k. Without touching the connector or spring with the fingers, install the connector in the sparkplug barrel. Be very careful that the connector is inserted straight into the barrel and not "cocked," since this can result in a cracked insulator or sparkplug barrel *[Figure 7—30]*.

l. Run the sparkplug lead coupling nut down finger tight. Hold the elbow or lead in proper position and tighten the elbow coupling nut to the recommended torque, using PWA-1683. Wrench. Never use an open-end wrench, since damage to the barrel insulator may result from side loading.

m. Check the sparkplug leads to be sure that they do not interfere with the engine and are not twisted.

7—47. REMOVAL OF ENGINE DEFLECTORS. Remove the nuts that secure the cylinder head deflectors to the cylinders. Release the spring loaded clamp on the rear side of the intercylinder deflectors and remove the cylinder head deflectors *[Figure 7—31]*. Remove the wing nuts which secure the intercylinder deflectors to the retaining clamps; *[Figure 7—32]* then remove the clamps and deflectors. The deflectors No. 7 and No. 8 cylinder cannot be removed until the clamp underneath the deflector has been loosened and the tee hose connection has been withdrawn from the deflector. Tag each deflector as it is removed so that it will be reinstalled in its proper location.

7—48. INSPECTION OF DEFLECTORS. Examine the deflectors for dents, bonding, and the condition of the paint.

7—49. INSTALLATION OF CYLINDER DEFLECTORS. Install the head deflectors and secure them with the necessary nuts *[Figure 7—33]*. Assemble the intercylinder deflectors and secure them with the clamps and wing nuts.

Figure 7—30. Install Connector

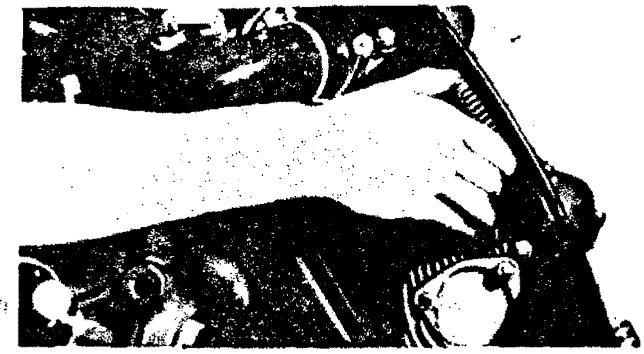


Figure 7—31. Release Spring Clamp

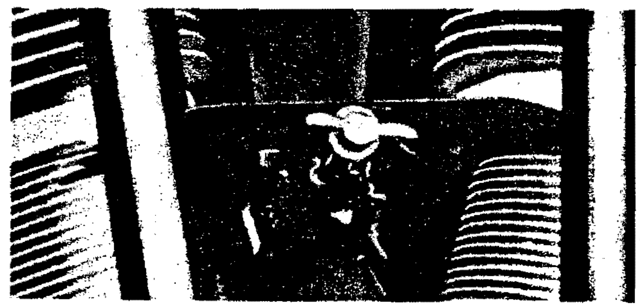


Figure 7—32. Remove Wing Nuts

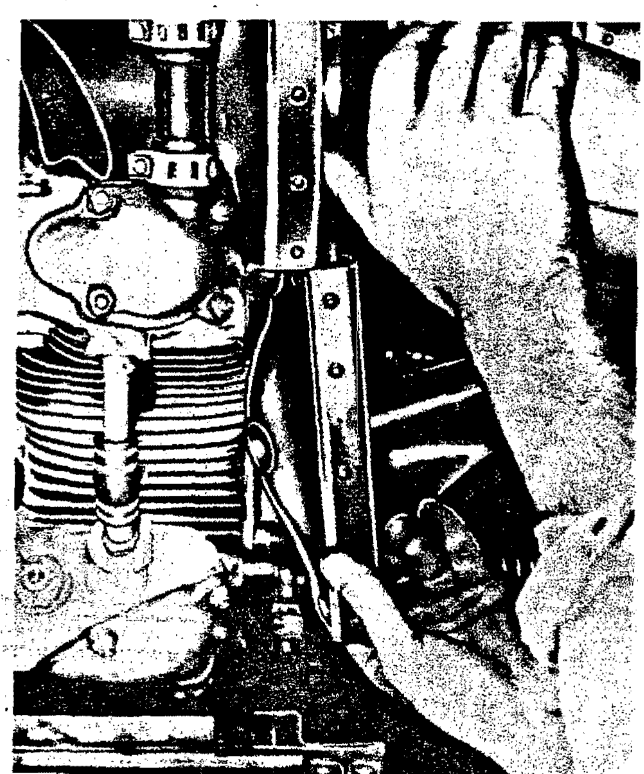


Figure 7—33. Install Head Deflector

7–50. REMOVAL OF MAGNETO.

a. Loosen the knurled coupling which secures the flexible manifold conduit to its distributor block cover elbow using PWA-1886 Wrench. Remove the screws which secure the elbow to the distributor block cover.

b. If the engine is equipped with Bosch magnetos, remove the three screws which secure the distributor block cover halves to the magneto. Remove the four screws holding each cover to the coil cover and the distributor block housing; then withdraw the cover halves. Remove the two distributor block fastening screws and lift out the distributor block. Wrap the distributor block in oiled paper to keep it clean and to prevent damage.

c. If the engine is equipped with Scintilla magnetos, remove the screw [*Figure 7–34*] which secures the distributor block halves of the magneto. Remove the safety pin, disengage the two spring locks on the distributor block cover; then remove the cover halves. Lift out the distributor blocks and wrap each block in oiled paper [*Figure 7–35*].

d. Remove the three bolts which secure the magneto to its mounting pad and lift off the magneto and rubber coupling.

7–51. INSTALLATION OF MAGNETO. Before installing a magneto on the engine, the internal timing of the magneto should be checked. To do this, remove the breaker compartment cover. Attach the red wire of PWA-2417 Indicator to the breaker points and ground the black wire to the magneto housing. Place a straightedge against the step on the breaker cam and turn the magneto drive shaft in the normal direction of rotation. The light of the indicator should flash on just as the straightedge comes into alignment with the timing marks on the magneto housing. On Scintilla magnetos the timing marks shown through the timing window should align at this point [*Figure 7–36*]. If this check indicates that the magneto is not properly timed, the breaker points should be adjusted as follows: with PWA-2417 still connected and the straightedge aligned, loosen the contact bracket screws or the breaker plate screws and turn the eccentric adjusting screw until the indicator light just flashes on, indicating that the points are just opening. Tighten the attaching screws.

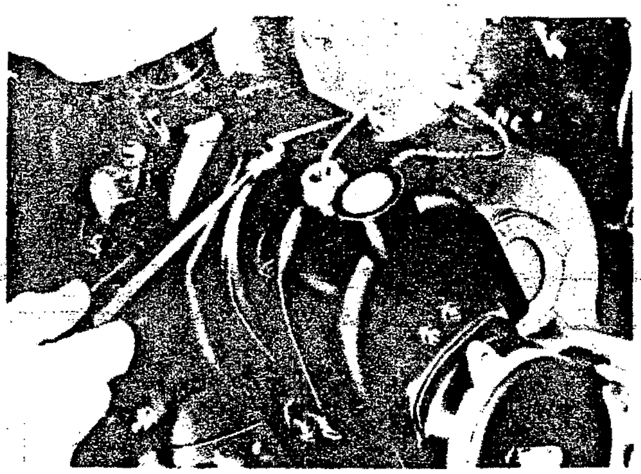


Figure 7–34. Removing Cover Screw

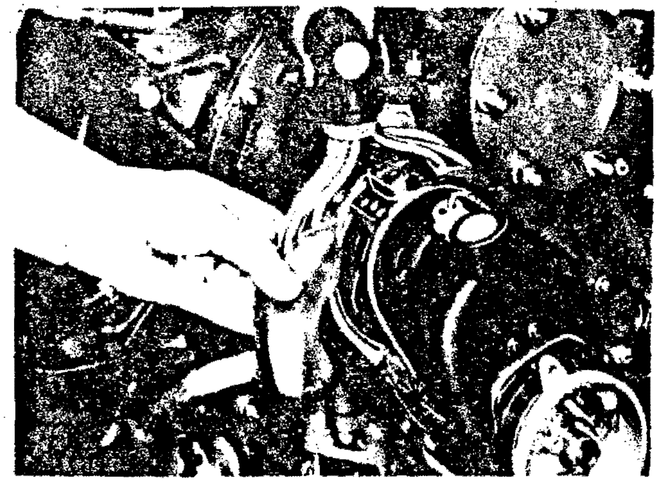


Figure 7–35. Remove Distributor Blocks

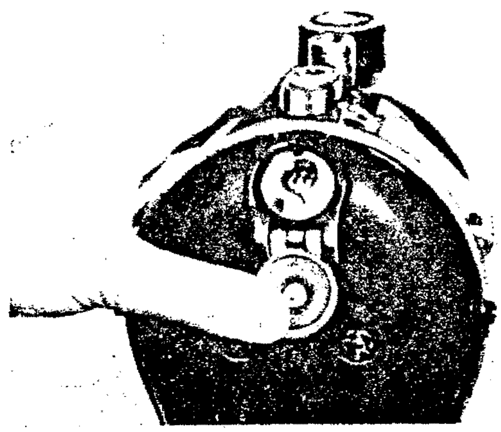


Figure 7–36. Timing Window

7–52. After the internal timing has been found to be correct, position the No. 1 piston 25 degrees before top center of its compression stroke as described in Paragraph 7–31.

Note

The accuracy of ignition timing is dependent, to a great extent, on accurately establishing the firing position of No. 1 piston. Personnel must exercise the greatest care in performing this operation.

7–52A. Mount the left or right magneto on the engine without installing the rubber coupling. Measure the distance between the magneto drive shaft and the magneto shaft couplings, making sure that the shafts are at their maximum distance apart. Rubber couplings are provided 1/32 inch oversize, identified by "B + 1/32 inch" mounted on the face. The coupling used should be .020 inch to .030 inch less in thickness than the distance between the two metal couplings. Remove the magneto from the engine.

7–53. With the straightedge in exact alignment and with the rubber coupling in place, rest the magneto on the magneto mounting pad *[Figure 7–37]*. Hold the magneto in place and rotate the rubber coupling between the two metal couplings until the rubber coupling can be engaged with the metal couplings without causing the magneto shaft to turn. Fit the magneto over the two dowel pins on the mounting pad *[Figure 7–38]*. Secure the magneto with the three bolts. Install the distributor blocks, the distributor cover and tighten the knurled coupling. Check to see that the magnetos are properly synchronized as directed in paragraph 7–31. After this check has been completed, lockwire the three magneto retaining bolts *[Figure 7–39]*.

7–54. REMOVAL OF IGNITION MANIFOLD. Disconnect all sparkplug lead connectors and remove them from the plugs. Install protector caps on the connectors. Remove the nuts which secure the manifold to the case. Loosen the knurled coupling which secures the flexible manifold conduit to its distributor block cover elbow using PWA-1886 Wrench. Remove the screws or bolts which secure the elbow to its distributor block cover. Remove the screws or bolts which secure the distributor block cover to the distributor block housing; then withdraw the cover from the distributor housing. On Bosch magnetos remove the two distributor block fastening nuts. Lift out the distributor block. To remove a cable from the distributor block loosen the cable piercing screw which fastens the cable to the block.

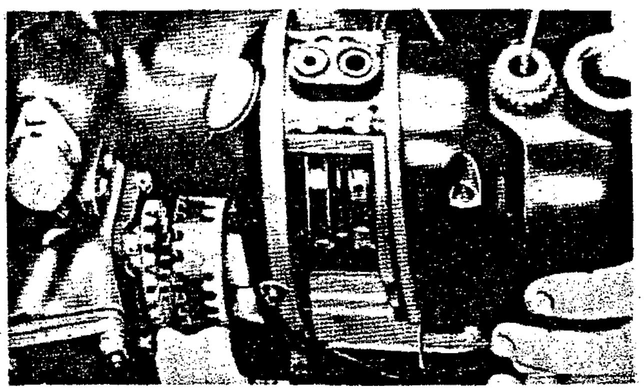


Figure 7–37. Align Magneto Coupling

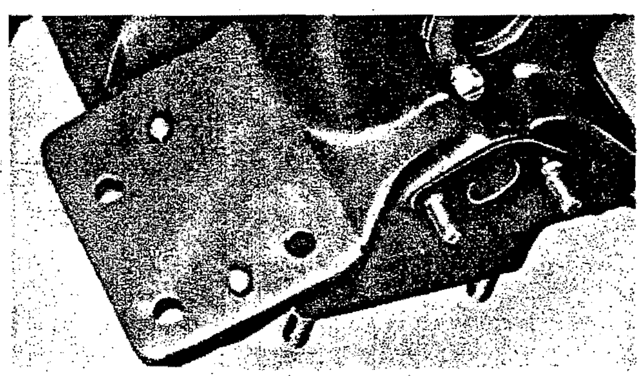


Figure 7–38. Two Dowel Pins

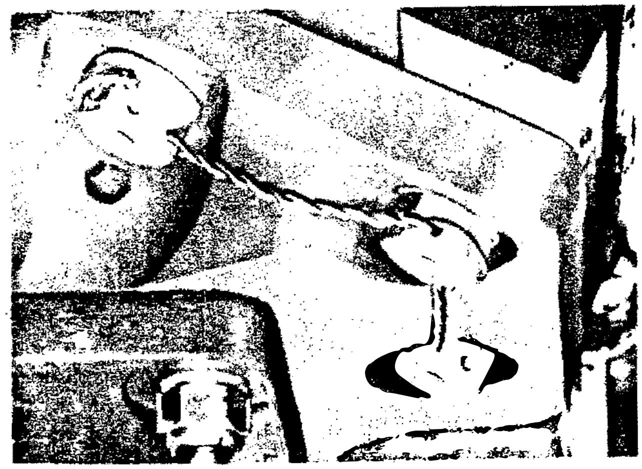


Figure 7–39. Lockwire Magneto Bolts

a. To remove the front manifold it is necessary to remove the pushrods and the intercylinder deflector.

b. To remove the rear manifold it is necessary to remove at least the top five intake pipes.

7–55. INSTALLATION OF IGNITION MANIFOLD. Insert the block in the magneto. On Bosch magnetos secure it in position with the two distributor block fastening nuts. Install the distributor block cover halves over the block. Install the screws which secure the distributor block cover halves. Secure the distributor block cover elbow to the cover with the screws or bolts and tighten the knurled couplings on the flexible manifold conduit, using PWA-1886 Wrench.

a. If the front manifold was removed, reinstall the pushrods and check and adjust the valve clearance. Replace the rockerbox cover gaskets and install the covers, and the intercylinder deflector.

b. If the rear manifold was removed, reinstall the intake pipes with new packings and copper gasket.

7–56. REPLACING MANIFOLD WIRE. If a continuity or high voltage test indicates a defective wire, check the table of wire lengths *[Figure 7–40]* and replace the wire as follows:

a. Remove the connector at the sparkplug end of the wire, and the sparkplug lead conduit from the ignition manifold. Loosen the coupling nut on the conduit and slide the conduit towards the rear. Determine in which direction the wire will pull the easiest; then splice and solder the new wire into the opposite end of the old wire. Dust the wire with talc or soapstone to prevent friction. Push the new wire through as the old wire is slightly pulled out. When the new wire is through far enough, cut it off to the proper length.

b. Remove ½ inch of insulation from the distributor block end of the wire, being careful not to cut any of the wire strands. Separate the strands and bend them back along the insulation. Mark a new copper ferrule with the proper number, using a metal stamp; then install the ferrule and secure it with PWA-1937-20 Crimping tool. Place the wire in its proper hole in the distributor block *(Figure 7–13)*, and secure it with the piercing screw. Push the wire through the sparkplug lead conduit; then secure the conduit to the manifold.

c. Remove ⅛ inch of insulation from the wire, being careful not to cut any of the wire strands. The insulation must bear firmly against the brass disc inside the sparkplug connector. Treat the ends of the insulation with an insulating lacquer. After the lacquer has dried, slide the connector into position on the wire. Bend the strands back over the wire opening in a radial pattern. Do not solder the wire.

7–57. REMOVAL OF ROCKERBOX COVERS. Unscrew the elastic stop nuts which secure the rockerbox covers to the cylinder heads *[Figure 7–41]* and remove the covers and gaskets. Rockerbox covers which are connected by intercylinder drain tubes should be removed in pairs *[Figure 7–42]*.

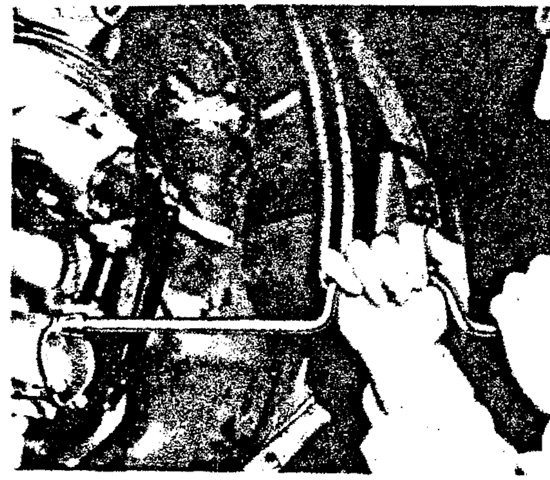


Figure 7–41. Rockerbox Cover Nuts

Engines Equipped With SB9R(U) — 3 Magnetos

No. of Distributor Block	Total Length Front Manifold	Total Length Rear Manifold	Wire Length from Rear Manifold to Left Magneto	Wire Length from Front Manifold to Right Magneto
No. 1	55"	37"	20½"	33"
No. 2	48¾"	53¾"	20½"	33"
No. 3	63¼"	68¼"	19"	31½"
No. 4	74⅔"	45⅔"	18½"	31"
No. 5	61½"	29½"	17½"	30"
No. 6	47¼"	45¼"	18"	30½"
No. 7	55⅞"	59⅞"	17½"	30"
No. 8	82⅔"	54⅔"	18½"	31"
No. 9	69"	39"	19"	31½"

Engines Equipped With SB9R(N) — 4 Magnetos

No. of Distributor Block	Total Length Front Manifold	Total Length Rear Manifold	Wire Length from Rear Manifold to Left Magneto	Wire Length from Front Manifold to Right Magneto
No. 1	57"	39"	18"	29"
No. 2	60"	55"	19"	30"
No. 3	62"	67"	17½"	28½"
No. 4	74"	45"	18"	29"
No. 5	61"	29"	19"	30"
No. 6	47"	45"	17½"	28½"
No. 7	54"	58"	18½"	29½"
No. 8	81"	53"	20"	31"
No. 9	69"	39"	19"	30"

DIMENSIONS OF FLEXIBLE CONDUITS

	Length	Inside Dimension	Outside Dimension
Magneto to Rear Manifold	10⅛" ± 1/16"	1 5/32" ± 1/10"	1.335" – 1.345"
Magneto to Front Manifold	21½" ± 1/10"	1 5/32" ± 1/10"	1.335" – 1.345"

Figure 7–40. Table of Wire Lengths

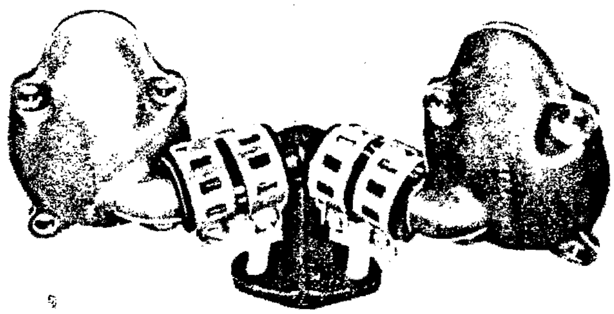


Figure 7-42. Rockerbox Covers

7-58. INSPECTION OF ROCKERBOX COVERS. Inspect for cracks and warpage. Check the rockerbox covers for flatness, using a .002 inch feeler gage and a surface plate. If necessary, face off the covers on a lapping plate, using a small amount of lapping compound [*Figure 7-43*]. This will insure that the covers bear evenly on their gaskets.

7-59. INSTALLATION OF ROCKERBOX COVERS. Place a new gasket on the rockerbox; then install the covers and tighten the nuts to the recommended torque [*Figure 7-44*].

7-60. REMOVAL OF PRIMER LINES. Disconnect all primer lines at the primer distributor [*Figure 7-45*], and at the Nos. 1, 2, 3, 8, and 9 cylinders to which they are attached [*Figure 7-46*]. Unfasten the clamps holding them to the intake pipes [*Figure 7-47*], and withdraw each line from the cylinder deflector through which it extends.

7-61. INSPECTION OF PRIMER LINES. Look for breaks, dents, pinched tubing, and broken unions. If necessary, replace with new primer lines.

7-62. INSTALLATION OF PRIMER LINES. Connect all primer lines at the primer distributor and insert the lines through the deflectors. Attach them to the cylinders to whcih they are attached. Fasten the clamps holding them to the intake pipes and supercharger section.

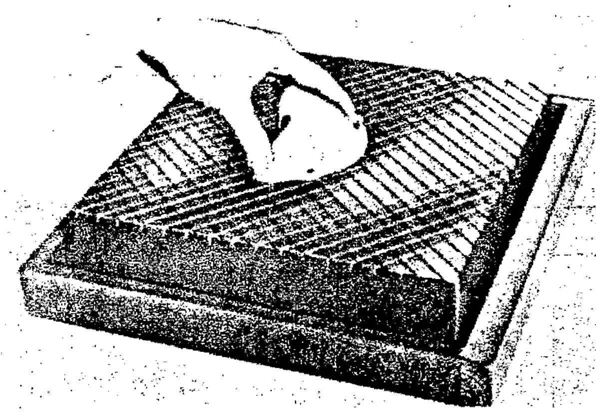


Figure 7-43. Lapping Rockerbox Covers

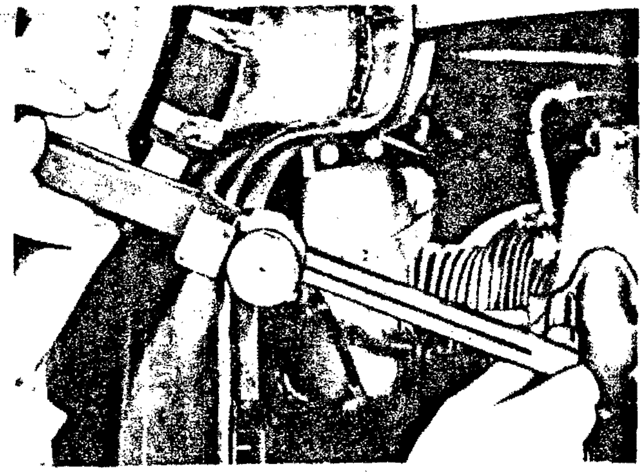


Figure 7-44. Torque Rockerbox Cover Nuts

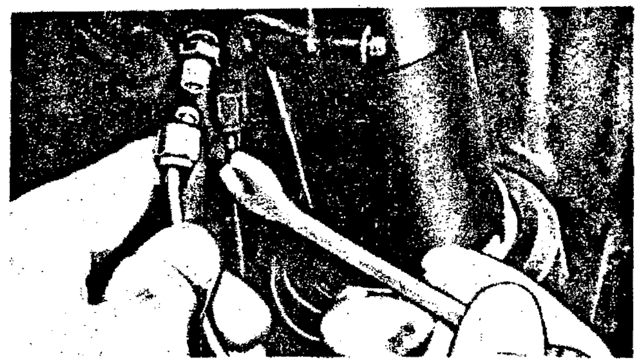


Figure 7-45. Primer Distributor

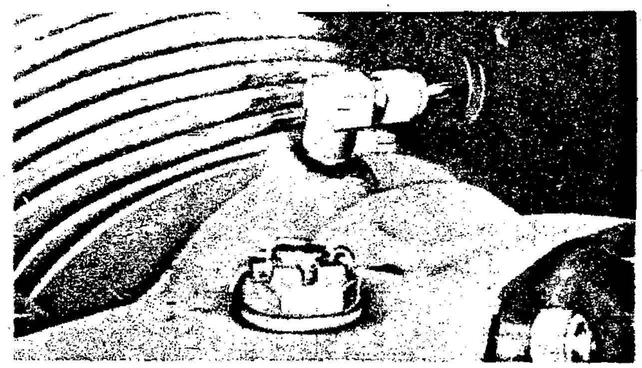


Figure 7-46. Cylinder Priming Elbow

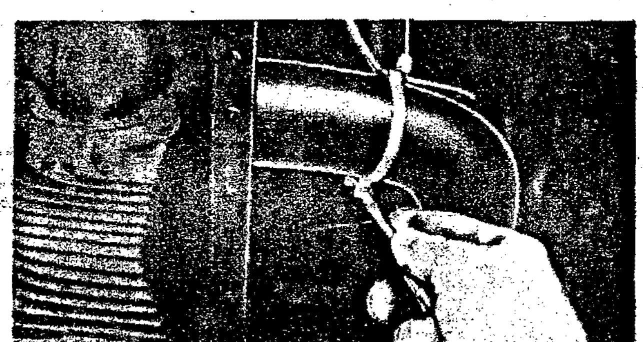


Figure 7-47. Primer Line Clamp

7–63. REMOVAL OF INTAKE PIPES *[Figure 7–48]* Loosen the nut at the supercharger section, using PWA-5072 Wrench. Remove the nuts and bolts at the cylinder end *[Figure 7–49]*; then remove the pipe.

7–64. INSPECTION OF INTAKE PIPES. Inspect for dents and cracks. Check condition of paint. Examine the nuts for breaks and condition of the threads. Replace packing, if it is not in good condition.

7–65. INSTALLATION OF INTAKE PIPES *[Figure 7–50]*. Install a flat rubber seal at the supercharger end of each intake pipe after first coating the seal with a thin even coat of insulating compound (Specification MIL-I-8660). Remove the supercharger case opening protector and place the pipe in position on the engine. Install the supercharger end of the pipe first and tighten the packing nut finger tight. Coat a copper gasket with insulating compound (Specification MIL-I-8660); then install it, split side forward, at the cylinder intake port. Secure the pipe to the cylinder with two self-locking nuts and one bolt. Safety-wire the bolt to the deflector assembly inter-ear bracket with a figure-eight tie *[Figure 7–51]*. Tighten the packing nut, using PWA-237 Wrench. Use care in tightening the nuts to avoid damaging the pipe.

WARNING

The insulating compound contains minutely ground silica and mica which may act as irritants to the eyes and skin. When the compound is handled frequently, it is suggested that gloves be worn.

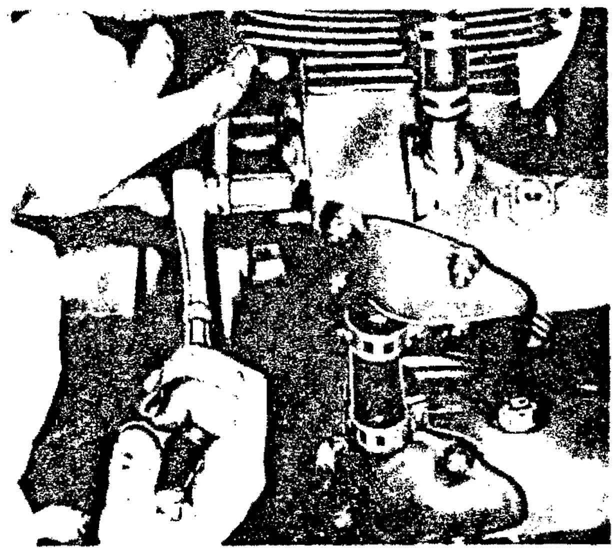


Figure 7–49. Intake Pipe Nuts and Bolts

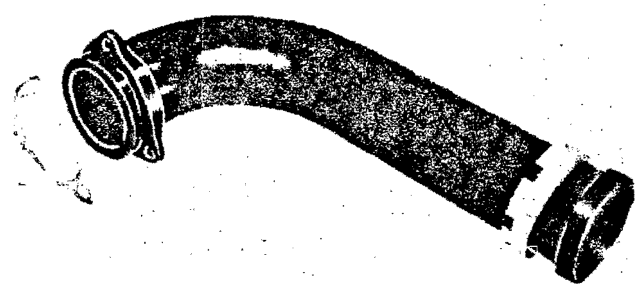


Figure 7–50. Intake Pipe Assembly

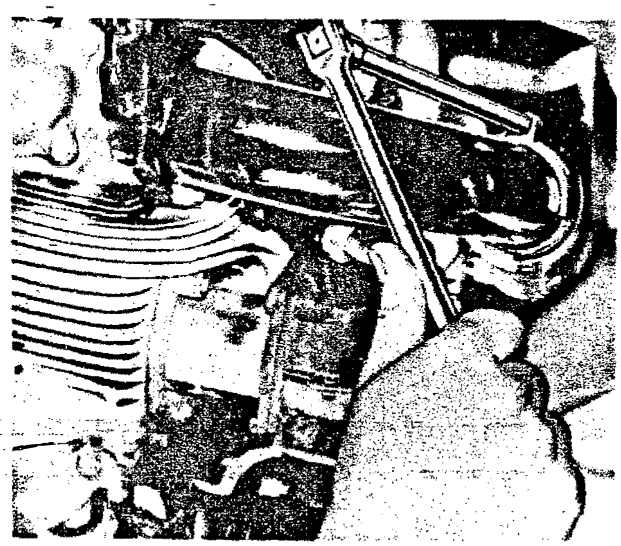


Figure 7–48. Pipe Gland Nut

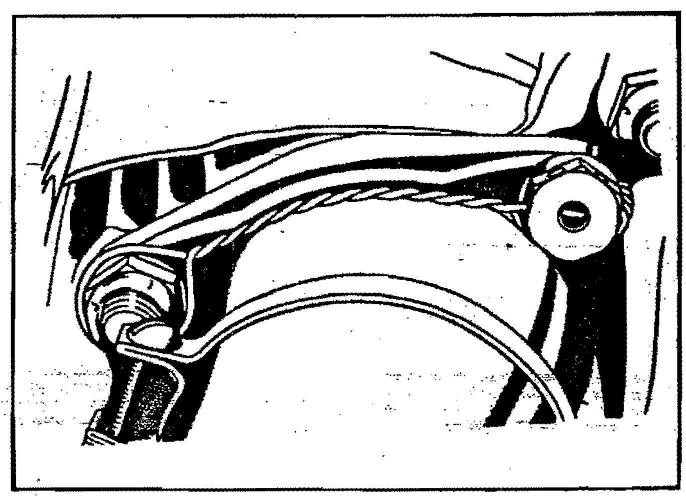


Figure 7–51. Lockwire Intake Pipe

7–66. REMOVAL OF PUSHRODS AND COVERS. Loosen all pushrod cover nuts at the cylinder ends first; then at the front case ends *[Figure 7–52]*, using PWA-3639 Wrench. Turn the propeller until the piston in the cylinder from which the pushrods are to be removed is at the top of its compression stroke (both valves closed). Depress the rockers with PWA-455 Depressor *[Figure 7–53]*, and remove the pushrods and covers.

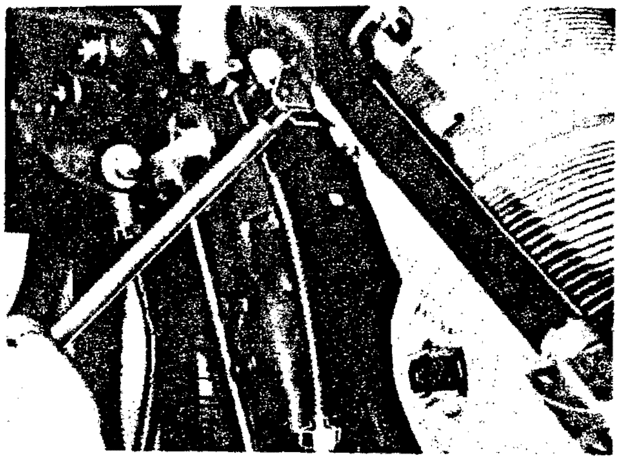


Figure 7–52. Loosen Pushrod Cover Nuts

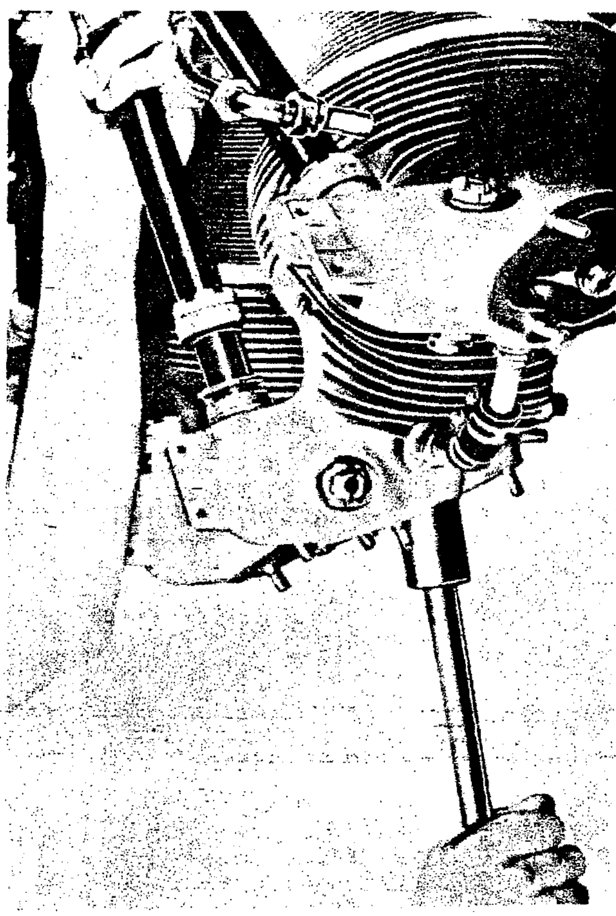


Figure 7–53. Depress Rockers

If desired the ballends may be removed using PWA-48 Puller *[Figure 7–54]* or PWA-2151-1 Drift.

7–67. INSPECTION OF PUSHRODS AND COVER Inspect for cracks and check the oil holes in the ba ends for clogging. Examine the rods for roundness ai straightness by rolling them on a plane surface *[Figu 7–55]*. Replace any ballends which are loose or exc sively worn. Check the covers for cracks and den Check the nuts at each end for condition of threads.

7–68. INSTALLATION OF PUSHRODS AND CO ERS. One of the ballends on each pushrod bears tl number of the cylinder into which it fits. The exhau rods are marked with an "Ex" after the cylinder nur ber and the intake rods are marked "in". Install tl

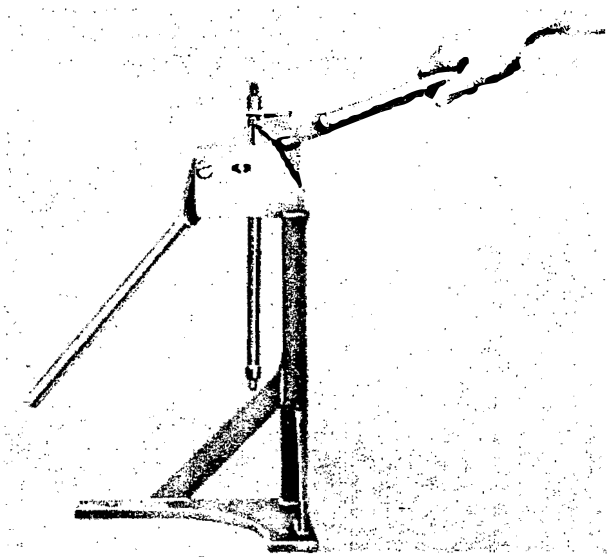


Figure 7–54. Remove Ballend

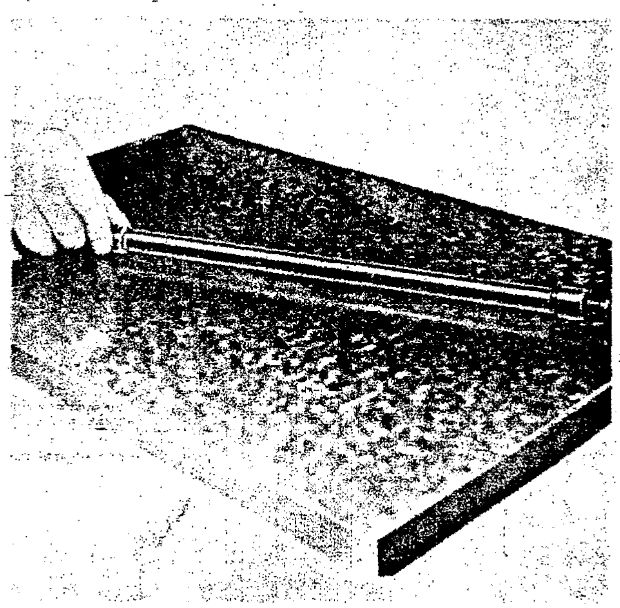


Figure 7–55. Check Pushrod

packing and seals in place in each gland nut *[Figure 7–56]*. Coat the ballends of each rod with oil. Assemble the pushrod and cover assembly with the marked end of the pushrod and the flared end of the cover tube toward the crankcase. Depress the rocker with PWA-455 Depressor and fit the corresponding pushrod and cover into position. If the valve tappet protrudes too far to allow installation of its pushrod, turn the crankshaft until the tappet has receded sufficiently to permit installation of the pushrod. After the pushrod and cover assembly are in place in the engine with the gland nuts secured finger tight, push the cover tube *firmly* against its seat on the tappet guide, turn down the gland nut, and tighten it to the recommended torque, using PWA-3639 Wrench. Next tighten the gland nut on the cylinder head end of the cover tube to the same torque, and lockwire both nuts *[Figure 7–57]*.

CAUTION

Never reverse the above sequence of operations as the packing on the tappet guide end might be pushed into the tappet compartment and be mutilated during engine operation.

7–69. If the pushrod cover was not removed from the crankcase, install the marked end of the pushrod toward the crankcase and guide the pushrod into the rocker socket while the cylinder is being installed on its pad. Check the valve stem-rocker clearance. Adjust if necessary as directed in paragraph 7–22.

7–70. REMOVAL OF CYLINDER ASSEMBLY. Observe the following instructions before removing cylinders: Remove the masterod cylinder, No. 5, LAST if it is in a group of two or more cylinders to be removed. Upon removal of the masterod cylinder, the pistonpin end of the masterod should be centered in the crankcase opening by using PWA-2834 Holder. The Holder allows rotation of the crankshaft without risk of damage to the cylinders, and the crankcase section, should rotation of the crankshaft, after removal of the masterod cylinder, become necessary.

CAUTION

Do not allow the masterod to move sideways at any time, as damage to the pistonrings and cylinder may result.

a. Turn the crankshaft until the piston of the cylinder to be removed is at the top of its compression stroke. Remove the palnuts *[Figure 7–58]*, then remove the cylinder flange nuts, using PWA-2006 or PWA-2399 Wrench and PWA-2398 or PWA-2411 Handle *[Figure 7–59]*, leaving one nut on until just prior to the removal of the cylinder.

CAUTION

If a nut is found to be loose or there has been failure of a stud, replace that stud and the two adjacent studs in accordance with paragraph 7–109. If only two adjacent studs have failed or two adjacent nuts have been found loose, the cylinder may be reused provided the nuts adjacent to the failed studs or adjacent to the

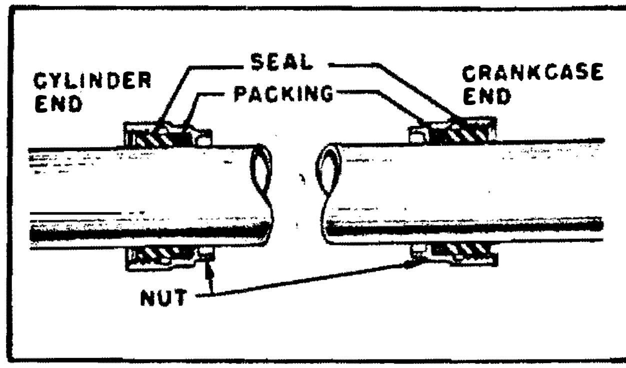


Figure 7–56. Pushrod Housing

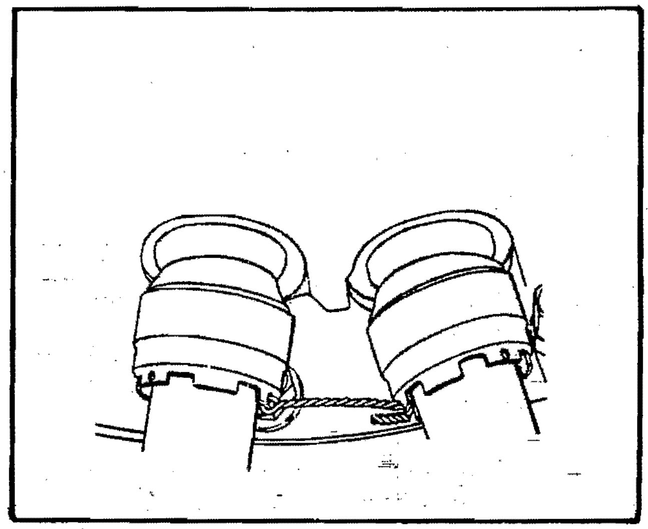


Figure 7–57. Gland Nuts Wired

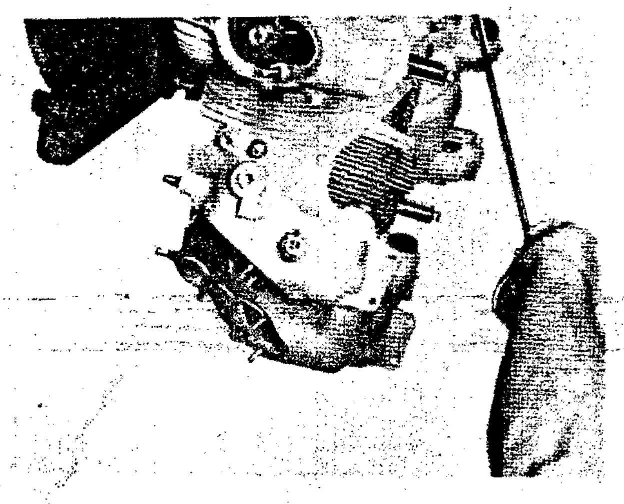


Figure 7–58. Removing Palnuts

loose nuts are found to be at least to the minimum torque (paragraph 7-124). If more than two adjacent studs have failed or if more than two adjacent nuts are known to have been loose during engine operation, the cylinder should be returned to overhaul and all studs on the cylinder mounting pad replaced.

b. Remove the cylinder *[Figure 7-60]* being careful that the pistonpin does not fall out. Remove the pistonpin, if necessary use PWA-4251-10 Pusher, and lift off the piston. Place the cylinder in an appropriate carrier to prevent damage to the fins and the bottom edge of the barrel.

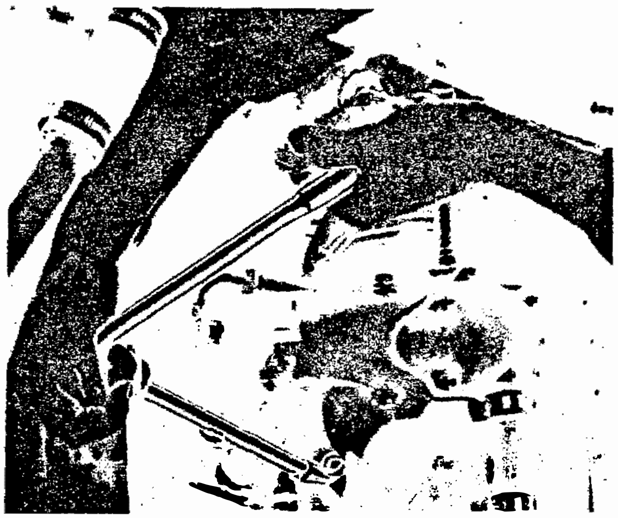


Figure 7-59. Removing Holdown Nuts

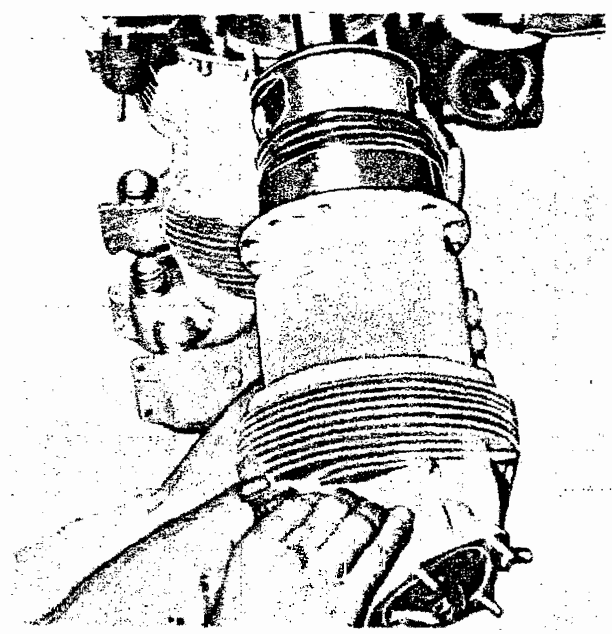


Figure 7-60. Removing Cylinder

c. Secure the rod with PWA-2834 Holder as soon a the cylinder is removed. Cover all openings in the crank case and the supercharger case to prevent the entranc of foreign matter.

7-71. REMOVAL OF VALVES AND SPRINGS. Plac the cylinder over a wood or fiber block shaped to fit th contour of the cylinder head. Compress the valve spring using PWA-459 Compressor, and remove the split lock *[Figure 7-61]*. Withdraw the upper washer and spring from the rockerbox *[Figure 7-62]*, and remove th safety circlets from the valve stems. Lift out the lowe washer using long nosed pliers *[Figure 7-63]*. Rais the cylinders from the block and lift out the valves *[Figure 7-64]*. Do not let the valves fall out and strike th cylinder walls. Place the valves in a rack so that they wil not be damaged.

7-72. REMOVAL OF ROCKERS AND ROCKER BEARINGS. Remove the nut from the inner (large) end of the rocker shaft *[Figure 7-65]*. Hold the inne

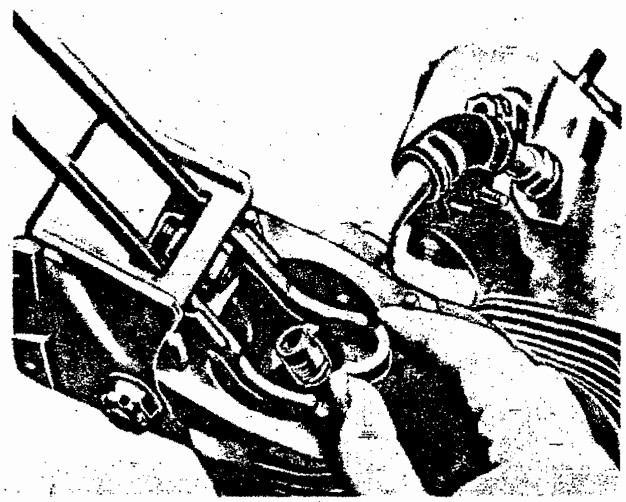


Figure 7-61. Removing Valve Lock

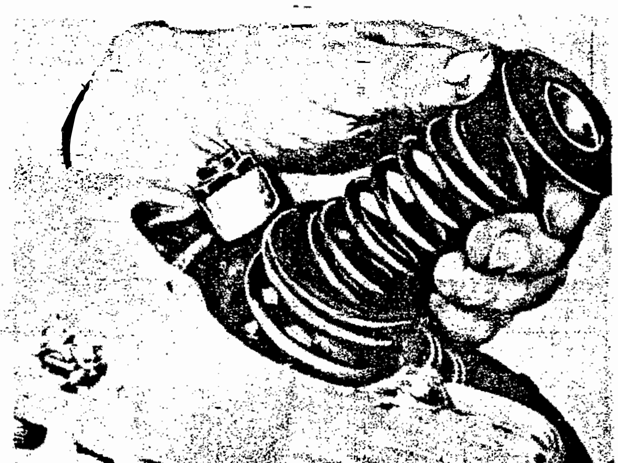


Figure 7-62. Removing Valve Spring

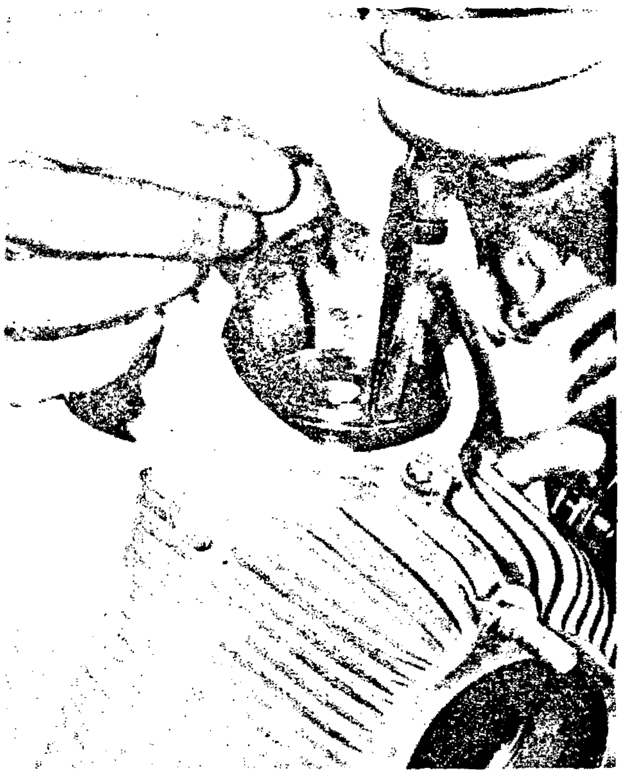


Figure 7—63. Lift Out Lower Washer

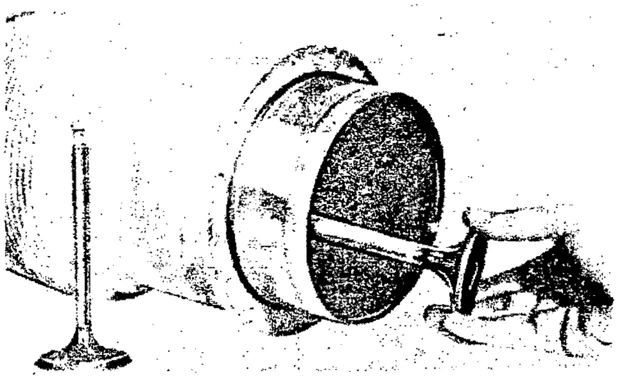


Figure 7—64. Removing Valves

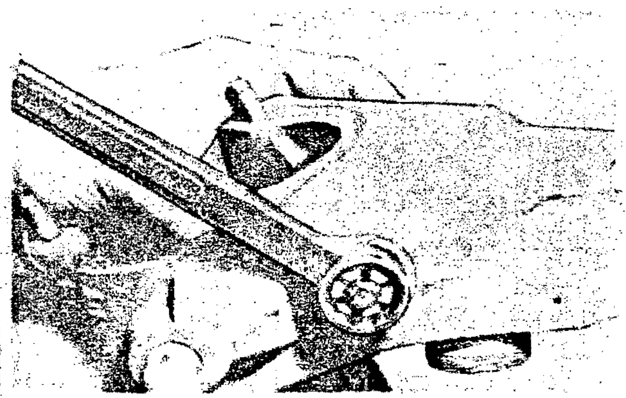


Figure 7—65. Removing Rockershaft Nut

end of the shaft, using a 9/16 inch wrench and remove the outer nut and washer. Drift out the shaft *[Figure 7—66]*, by driving on the small end with a fiber drift; then lift out the rocker *[Figure 7—67]*. If the bearing is to be removed place the rocker on an arbor press and press out the rocker bearing, using PWA-614 Drift and Base *[Figure 7—68]*.

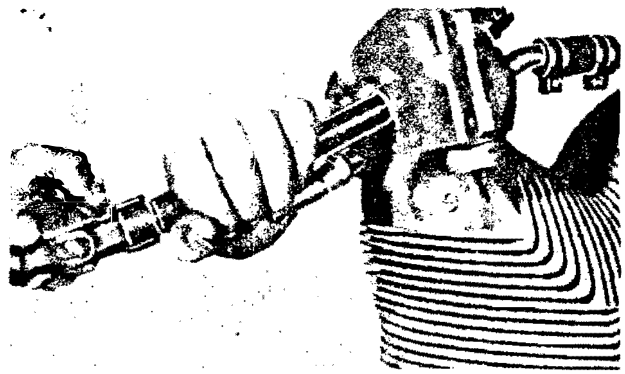


Figure 7—66. Drift Out Rockershaft

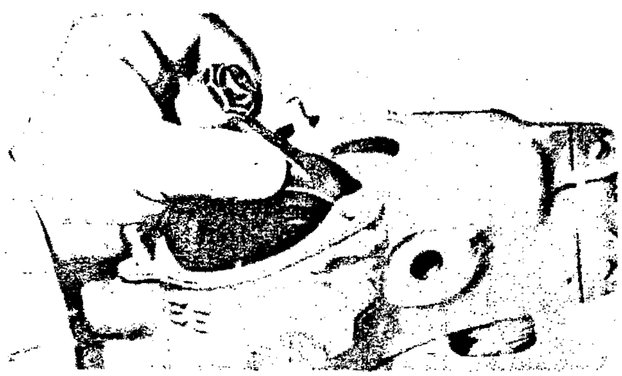


Figure 7—67. Lift Out Rocker

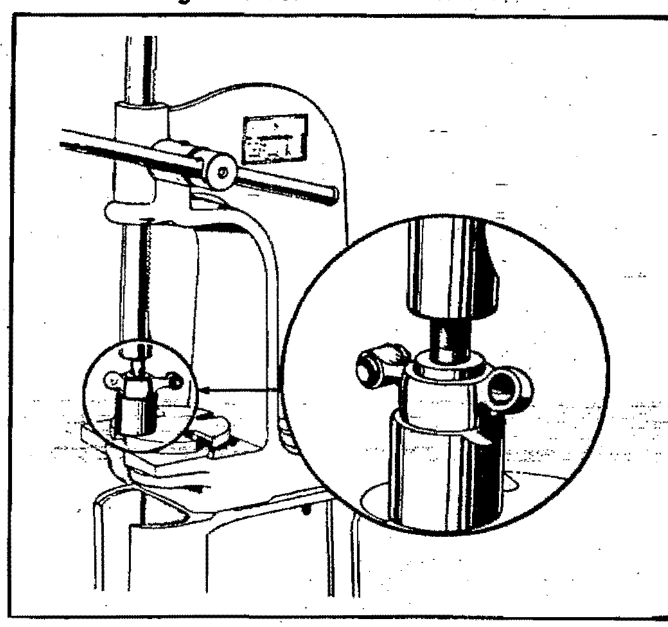


Figure 7—68. Removing Rockerbearing

7–73. INSPECTION OF CYLINDER RELATED PARTS.

7–74. CYLINDER BARRELS. Using PWA-2630-20 Gage and pencil carbon paper, check the cylinder flange for flatness and squareness. If the flange is uneven or distorted and providing the distortion does not exceed .003 inch, lap the flange, using PWA-2199 Lap *[Figure 7–69]*. If the distortion exceeds .003 inch, replace the cylinder assembly.

7–75. The greatest wear in a cylinder barrel usually occurs at the rear, slightly toward the thrust side, where the upper pistonring reaches the top of its travel. This wear extends only a short way down the barrel, and the main part of the barrel's choke is not appreciably affected unless the condition is extreme. As wear increases at the top of the barrel, a step is formed. If this step exceeds .006 inch at any part of the circumference, replace the cylinder assembly.

7–76. Check the bore of the barrel for out of roundness. The bore should not be more than .006 inch out of round. It is permissible to let the diameter of the barrel at the step location reach .006 inch over the diameter of a standard bore, as measured at the bottom of the barrel, providing .006 inch out of roundness is not exceeded. If the diameter of the barrel at the step location or the out of roundness of the barrel is found to be excessive before 1500 hours of service, and providing the cylinder head is still in good condition, return the cylinder to stock and hold for return to the manufacturer for barreling. Replace the cylinder assembly.

7–77. Use PWA-1313-T-3 Gage and PWA-312-11 Indi tor to measure the wear and out of roundness of the ba *[Figure 7–70]*. Set the needle of the indicator at zero mark in the gage, which represents the basic di eter of the cylinder barrel. The presence or extent of w and distortion may be determined by moving the ind tor along the length of the barrel while looking for fluctuations in positive or negative directions on indicator in various radial positions. A positive read at the top of the barrel indicates the amount of ch left in the tapered (pre-ground) type of barrel. By serving any difference in the diameters of the cylind at a given distance from the end of the barrel, the out roundness of the cylinder at that location may be de mined. A step at the top may be calculated by subtr ing the indicator reading obtained above the top of upper ring travel from that obtained at the exact top the upper ring travel.

7–78. Examine the cylinder barrel for cracks, scori damaged fins, and other irregularities. Check the c dition of metallized surfaces.

7–79. CYLINDER HEADS. Examine the fins arou the heads for cracks and breaks. Blend any sharp c ners to broken fins before installing the cylinder. spect areas adjacent to the sparkplug bushings for cra and also around the exhaust ports. Cowl mounting l may be repaired as follows: Thoroughly clean the s face of the break and the area immediately surroundi

Figure 7–69. Lap Cylinder Flange

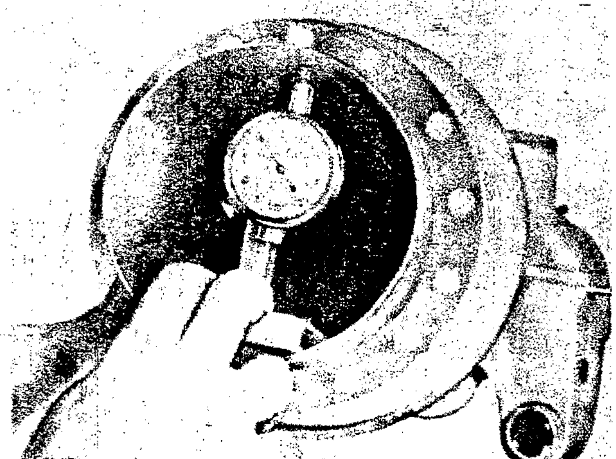


Figure 7–70. Inspect Cylinder Barrel

the lug. Using a welding torch adjusted to give a soft neutral flame and an Oxweld Linite welding rod (5 percent silicon) with No. 4 flux, build up the lug with the aid of a sheet iron template approximating finished dimensions. Use of a template will help to avoid considerable hand filing. Finish the lug by hand filing or with a hand burring tool. Locating on a normal cylinder from the rockershaft bushing holes, the valve guide bushing holes or both, make a simple drill jig. Using a hand drill and this jig, drill the holes in the rebuilt lug. It is necessary to bake or reheat the head after the repair has been made.

7–80. CYLINDER FIN BREAKAGE. If more than 8 inches in length of any one fin is completely broken off or if the total fin breakage on any one cylinder head exceeds 20 square inches, the cylinder must be replaced. Where adjacent fins are broken in the same area, the total permissible length of breakage is 6 inches on any two adjacent fins and 4 inches on any three adjacent fins, 2 inches on any four adjacent fins, one inch on any five adjacent fins, etc. Any roughness or sharp corners should be carefully blended into the adjacent surface to eliminate a possible source of new cracks.

Note

The length of limits given are measured at the base of the fin. "Fin area" is defined merely as the total area exposed (both sides of fins) to cooling air.

7–81. CYLINDER FLANGE NUTS AND STUDS. All cylinder flange studs and nuts should be examined for cracks, damaged threads and other visible defects. Clean the threads of the studs and nuts thoroughly, using a hand wire brush if necessary. Remove any roughness or burrs on the nuts, studs, or cylinder flanges. Also observe replacement requirements as outlined in paragraph 7–70a.

7–82. PISTONS. Inspect the pistons ***[Figure 7–71]*** for cracked heads and skirts, broken or distorted ring lands, scored or worn pistonpin holes, excessive carbon deposits, broken rings, or rings seized in the grooves. Rings may be removed with PWA-1791 Pliers ***[Figure 7–72]***. Clean ring lands. Inspect piston head for dishing. Check the width of the grooves by measuring the side clearance of standard size rings. Check the pistonring end clearance ***[Figure 7–73]***. Replace piston and rings together with cylinder if necessary, the rings of which have been lapped.

7–83. PISTONPINS. Inspect the pistonpin for scoring, cracks, excessive wear, rust pitting, and out of roundness. Check the fit of each pistonpin in its bushing in the corresponding linkrod and in its bosses in the corresponding piston.

7–84. ROCKERS. Examine the rockers for cracks and galling. See that no oil passages are obstructed. Inspect the socket in the pushrod end of each rocker for looseness and excessive wear. If the surface is rough or uneven, the socket should be replaced. Check the condition of the threads in the valve end of the rocker.

7–85. VALVE SPRINGS. Inspect for cracks, broken ends, inadequate spring pressure ***[Figure 7–74]***, rust and improper length.

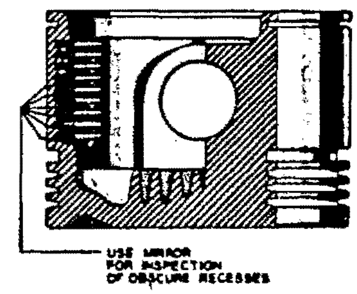


Figure 7–71. Inspecting Pistons

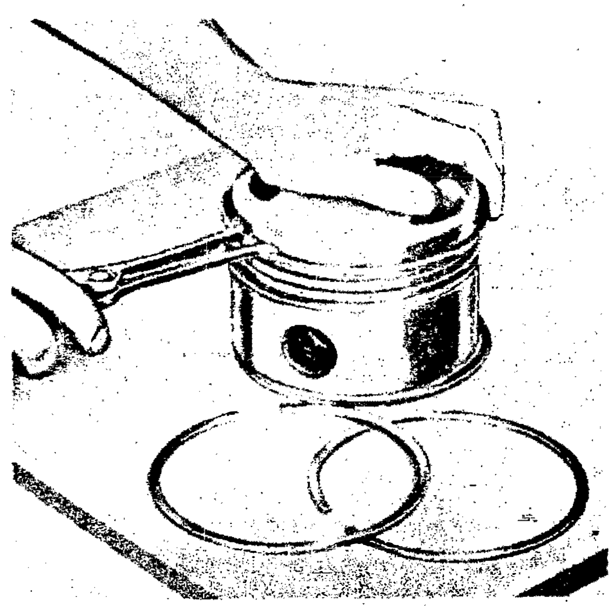


Figure 7–72. Removing Pistonrings

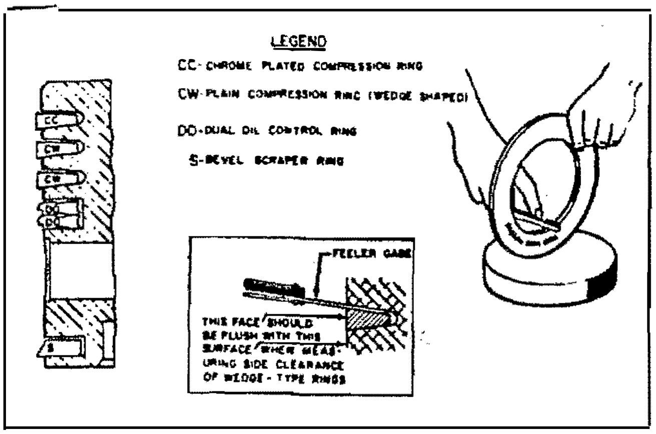


Figure 7–73 Pistonring Gaps

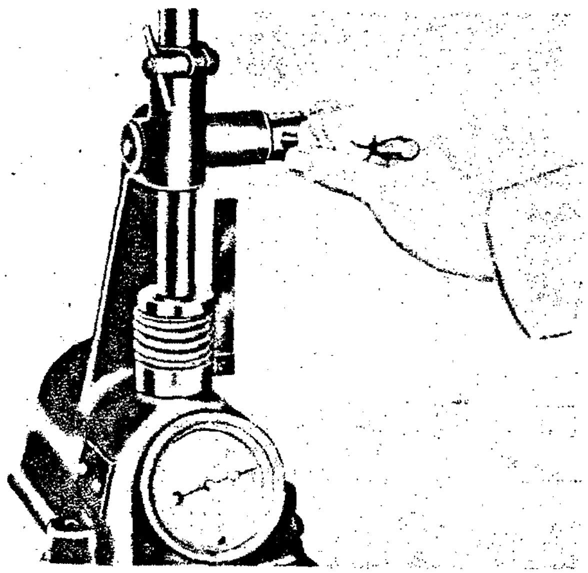


Figure 7–74. Spring Pressure

7–86. VALVE LOCKS. Examine for burrs and galling. Check the fit of each pair of locks with its valve. A lock should have no perceptible movement when it is in place of the valve, and the radii of the lock and valve should coincide.

7–87. VALVE SPRING WASHERS. Inspect for cracks, pitting, and galling.

7–88. EXHAUST VALVES. Examine the exhaust valve for stretching and drawing of the valve stem, using PWA-737 Gage *[Figures 7–75* and *7–76]*. Inspect for poor seating surface, erosion *[Figure 7–77]* and capping. Remove excessive carbon.

WARNING

To avoid possible injury to personnel, unserviceable sodium-filled exhaust valves should be carefully disposed of. (Refer to TM 1-2R-1-67.)

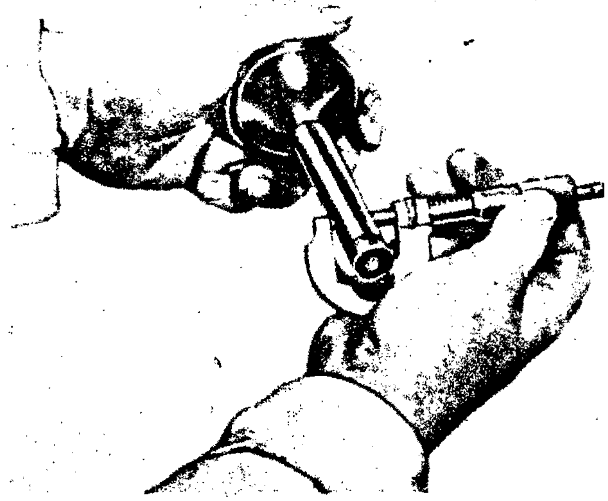


Figure 7–75. Valve Stem Wear

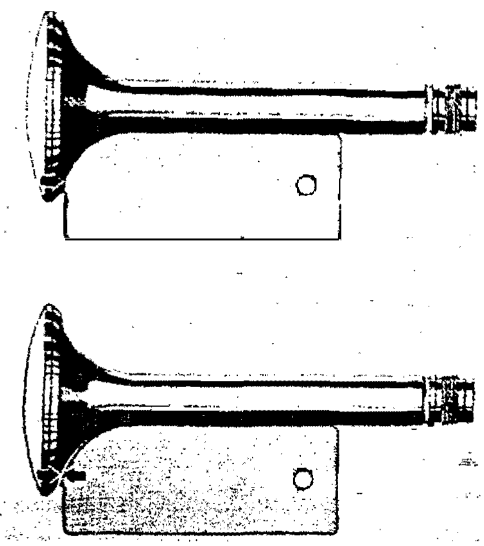


Figure 7–76. Valve Stretch

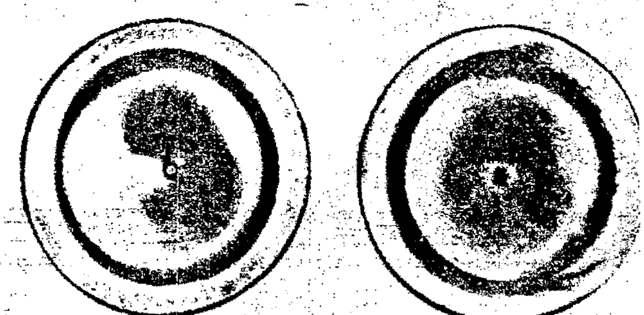


Figure 7–77. Erosion

7–89. STUDS. Check all studs for looseness, possible fractures at the base of the threads, and projection length. Examine for cracks, nicks, burrs, and bent studs. Replace all damaged studs.

7–90. FAILED CYLINDER ASSEMBLIES. Experience has proven that an engine which has suffered a valve or cylinder head failure may be successfully returned to service if the cylinder assembly is replaced. In order to understand the success of this practice, it is necessary to review the circumstances which cause cylinder head and valve failures.

a. Cylinder heads usually fail when the tensile strength of their material has been lowered by excess heat and when the pressure inside the cylinder is extremely high. These two factors can cause rupture of the head. The same conditions may exist in other cylinders which do not fail, and they regain their tensile strength when they have cooled. Because of this regeneration, it is clear that the cylinders are not permanently weakened by the excessive temperatures and pressures to which they are subjected.

b. Exhaust valve failures can usually be traced to an adverse condition in the particular cylinder in which they fail. For instance, there may have been insufficient valve clearance, valve sticking, high cylinder head temperature, or other factors which tend to weaken the valve.

c. Although experience has proven that engines with valve or cylinder head failures may be successfully returned to service, it is not recommended that all engines subjected to these failures be kept in service. Before replacing the cylinder be certain that no metal particles have entered the engine. Examine the linkrod to ascertain whether or not it has been bent or damaged. Make a visual check of all combustion chambers to determine whether or not they have been damaged in any way. Examine the pushrods for damage also.

d. After the installation of a new cylinder assembly, a complete compression check should be made. The engine should then be given a complete ground check. After this ground check, a second compression check should be made. In addition, make a thorough visual check of the engine, paying particular attention to the condition of the cylinder flange studs, cylinder heads, and combustion chambers.

e. Regardless of the number of cylinders being replaced, the engine is to be run-in for ½ hour at 1000 RPM, ½ hour at 1400 RPM, and ½ hour in short spurts to 2000 RPM. During this run-in the cylinder head temperature should not exceed 205°C (401°F).

7–91. INSTALLATION OF ROCKER AND SHAFT. Install the rocker bearings in the rockers, using PWA-614 Drift and Base. Make sure the oil holes in the bearings line up with the oil holes in the rockers. Place each rocker in position and insert the shaft through the bushings and rocker. Install the oil seal, washer, and nut on the small end of the shaft; then, holding the large end of the shaft with a 9 16 inch wrench, tighten the nut to the recommended torque. Install the oil seal, gasket, and nut on the large end of the shaft, and tighten the nut to the recommended torque. Cotter the nuts.

7–92. INSTALLATION OF VALVES. Clean and oil the valve guides and stems. Insert the valve stems in their guides and place the cylinder over a domed wooden block to prevent the valves from falling. Install the lower valve spring washer, inner and outer valve springs, and the upper valve spring washer. Compress the valve springs, using PWA-459 Compressor, and install the split locks.

7–93. INSTALLATION OF CYLINDER AND PISTON. If the masterod cylinder (No. 5) has been removed, it must be installed first. Coat the cylinder walls, pistonpin, piston, and pistonrings with oil. Install the oil seal ring under the flange of the cylinder. Rotate the crankshaft until the masterod or linkrod of the cylinder is at the full outward position. Each piston, pistonpin, and cylinder has a number denoting its proper position. Install the piston and pin with their numbered sides toward the front of the engine. Stagger the ring gaps and apply a generous coating of oil to the rings; then compress the outer rings, using PWA-249 Clamp, and slide the cylinder over the ring *[Figure 7–78]*. Compress the scraper ring with the clamp; then slide the cylinder over the ring and into place against the mounting pad. Center the cylinder with two locating nuts and install washers and nuts on the other studs.

CAUTION

See CAUTION to paragraph 7–70a.

Tighten the flange nuts to the recommended torque *[Figure 7–79]*. Install locknuts over the flange nuts, running them down finger tight. Tighten the locknuts ¼ turn more. Any cylinder flange locknut which becomes loose or is backed off for any reason after wrench pressure is applied must be removed and discarded. Regardless of the number of cylinders being replaced, the engine is to be run for ½ hour at 1000 RPM., ½ hour at 1400 RPM, and ½ hour in short

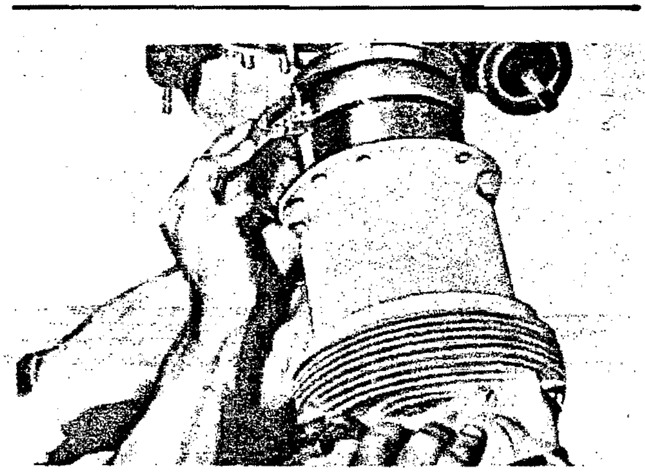


Figure 7–78. Installing Cylinder

spurts to 2000 RPM. During this run-in the cylinder head temperature should not exceed 205°C (401°F).

CAUTION

Because of the necessarily special design of cylinder flange nut wrenches, particular care should be exercised in tightening nuts. See that the cylinder flange nut wrench, the extension, and the torque indicating handle are so assembled that the handle is directly opposite the box end of the wrench, and apply torque by rotating assembly as a unit. Do not let the shaft of the wrench twist to one side.

7—94. REMOVAL OF OIL PRESSURE RELIEF VALVE. Remove the acorn shaped cap from the oil pressure relief valve. Remove the oil pressure relief valve body, then withdraw the spring and plunger. Use PWA-671 Wrench to remove the valve seat from the rear case *[Figure 7—80* and *7—81]*.

7—95. INSPECTION OF OIL PRESSURE RELIEF VALVE. Check the tension of relief valve spring. Note the condition of the valve in valve seat. Lap these parts together with a very fine grade of lapping compound to form a perfect seat. Guide surfaces of valve should have a free sliding fit in the seat. Polish guide surfaces with crocus cloth (Specification P-C-458) and oil.

7—96. INSTALLATION OF OIL PRESSURE RELIEF VALVE. Install the valve seat in the rear case, using PWA-671 Wrench. Insert the plunger and spring into the oil pressure relief valve body. Fit a new gasket under the flange on the valve body and screw the body into the rear case. Adjust the engine oil pressure. Install a gasket and screw the acorn shaped cap on the outer end of the valve body. Lockwire the cap to the adjacent squarehead plug *[Figure 7—82]*.

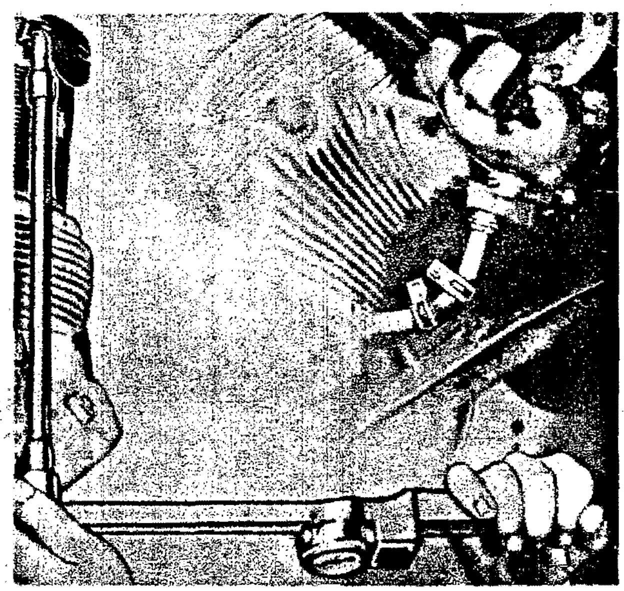


Figure 7—79. Torquing Holdown Nuts

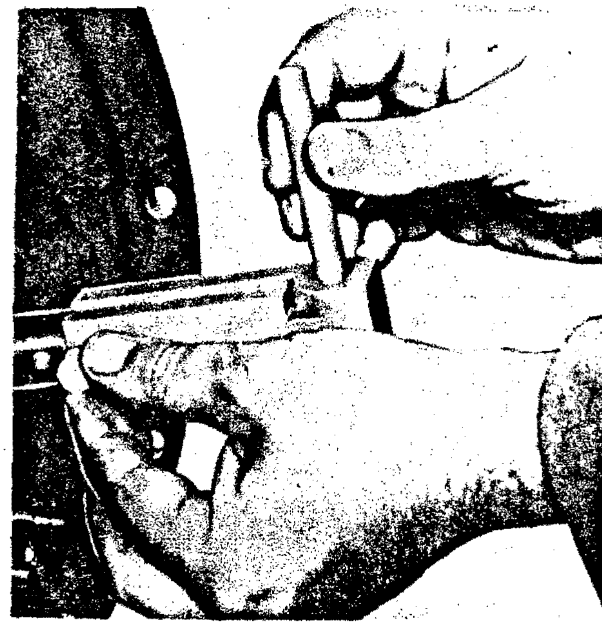


Figure 7—80. Installing Wrench

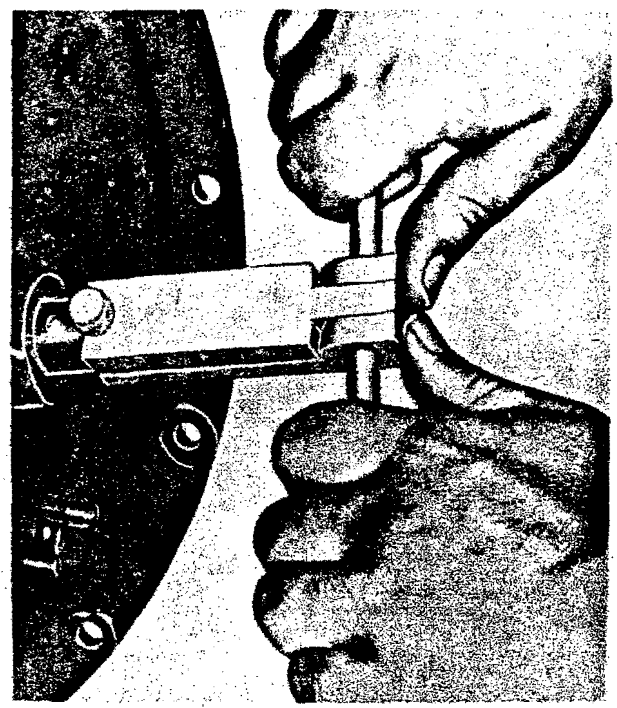


Figure 7—81. Removing Valve Seat

7—97. REMOVAL OF OIL PUMP. Remove the nuts attaching the oil pump to the rear case. Attach PWA-1327 Puller to the oil inlet port studs and pull the pump from the rear case.

7—98. INSPECTION OF OIL PUMP. *[Figure 7—83]* Inspect the teeth for pitting and uneven contact. The gears should turn freely and show no indication of interference with pump body. Oil passages must be clean. Inspect the body for cracks, scoring, and condition of

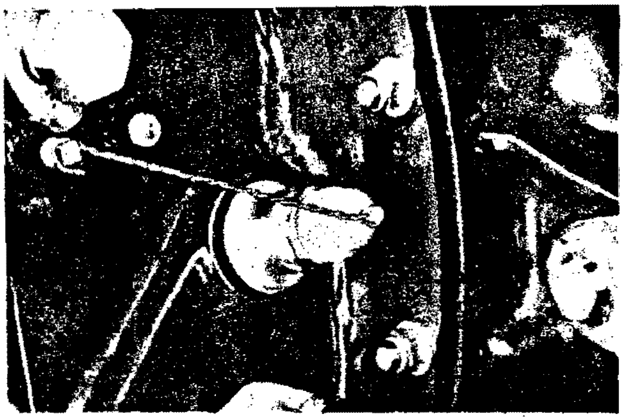


Figure 7—82. Relief Valve Cap

paint. Check the oil seal rings for scoring and loss of tension.

7—99. INSTALLATION OF OIL PUMP. Install the oil seal rings in position on the O.D. of the pump body. Fit a new gasket over the mounting flange on the oil pump housing. Install the oil pump in the rear case, engaging the drive gear with the accessory intermediate drive gear. Attach the pump to the rear case with washers and nuts.

7—100. REMOVAL OF OIL STRAINER. Using PWA-228 Wrench, unfasten the oil strainer cover nut; then remove the cover, spring, oil strainer, and check valve assembly *[Figure 7—84]*.

7—101. INSPECTION OF OIL STRAINER. *[Figure 7—85]* Examine the strainer for the presence of metal chips or foreign matter which may indicate a failure or some other unsatisfactory condition in the engine. Inspect the oil strainer for distortion or splits at the soldered joints. Check the fit of the strainer in its chamber in the rear case. Inspect the oil check valve to see that it is free and seats properly. Check the spring pressure and examine the cover for cracks and condition of paint.

7—102. INSTALLATION OF OIL STRAINER. Insert check valve assembly, oil seal and oil strainer into chamber in rear case. Center a new oil chamber cover gasket on cover, using a small amount of lubricating grease (Specification MIL-L-3545) on both sides of the gasket. Install the gasket and cover. The gasket is to be installed with the smooth side toward the shoulder of the cover (the crimped or asbestos-exposed side toward the engine). This procedure keeps the gasket from turning and wearing a pattern into its sealing part while the cover is being tightened. Tighten the cover with PWA-228 Wrench. Lockwire the cover.

7—103. OIL SUMP REMOVAL. Unscrew the elastic stop nuts which secure the rockerbox covers of cylinders No. 5 and No. 6 which are next to the sump. Disconnect the hose connecting them to the sump and remove the covers and hose. Remove the suction tubes from the rear of the sump. *[Figure 7—86]*. Remove the nuts which fasten the upper ends of the tubes to the right hand side

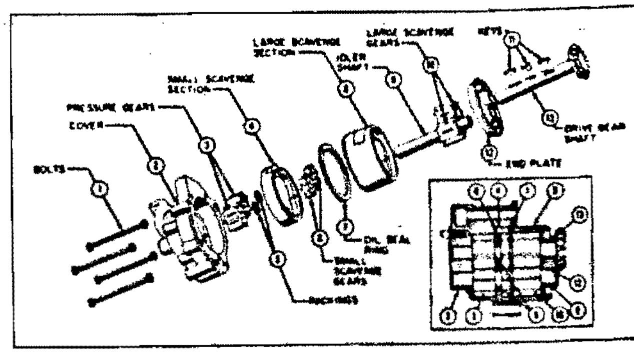


Figure 7—83. Oil Pump

of the rear section. Unfasten the clamps and remove the tubes. Unscrew the four nuts securing the oil sump to the engine, using a ½ inch universal socket and ratchet. Pull the sump from the engine *[Figure 7—87]*.

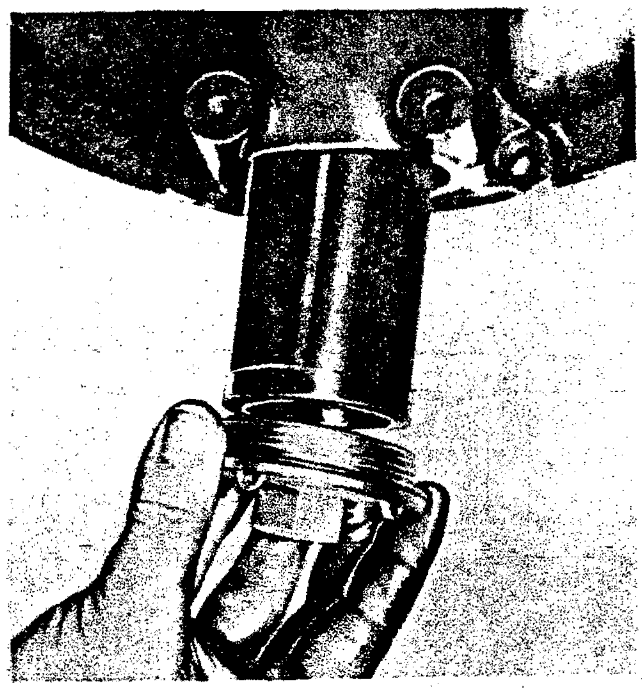


Figure 7—84. Withdrawing Strainer

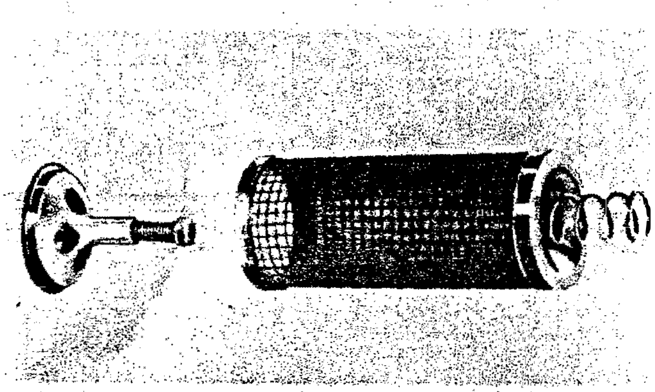


Figure 7—85. Oil Strainer

7–104. INSPECTION. Inspect the sump for cracks and condition of the paint. Seating surfaces must be clean and smooth. Check scavenge strainer for distortion and condition of soldered joints. Make sure that the strainer is thoroughly cleaned before it is reinstalled.

7–105. INSTALLATION. Place the intercylinder sump deflector on the sump while the latter is still on the bench and secure it. Screw the oil drain plugs into the bottom of the sump and tighten them with a 2 inch box wrench. Place a new gasket on each mounting flange of the sump. Install the sump on its mounting pads. Screw the fiber nuts on the studs using a ½ inch universal socket and speed handle. Secure the two oil suction tubes to the sump and rear case, tightening the nuts with a ½ inch socket and speed handle, and install the tube clamps. Reinstall rocker box covers and hose connections.

7–106. CARBURETOR REPLACEMENT. *[Figure 7–88]* Depending upon the particular installation, remove the carburetor air scoop and disconnect the throttle control linkage and mixture control linkage. Remove the four nuts which secure the carburetor to the adapter, and lift out the carburetor. Install the new carburetor and secure it with the four nuts. Connect the control linkages and reinstall the carburetor air scoop. Adjust the throttle stop and idle mixture strength as directed in paragraph 7–32.

7–107. STUD REPLACEMENT. Loose or broken studs normally can be replaced without damage to the threads in the hole. Select the proper oversize stud. Broken studs can generally be removed by using the hole in the flange of the mating part as a guide for a drill which is used to spot a center in the broken stud after which a smaller drill is used to drill out the central portion of the stud. Drive some type of steel extractor, such as an Easy-Out

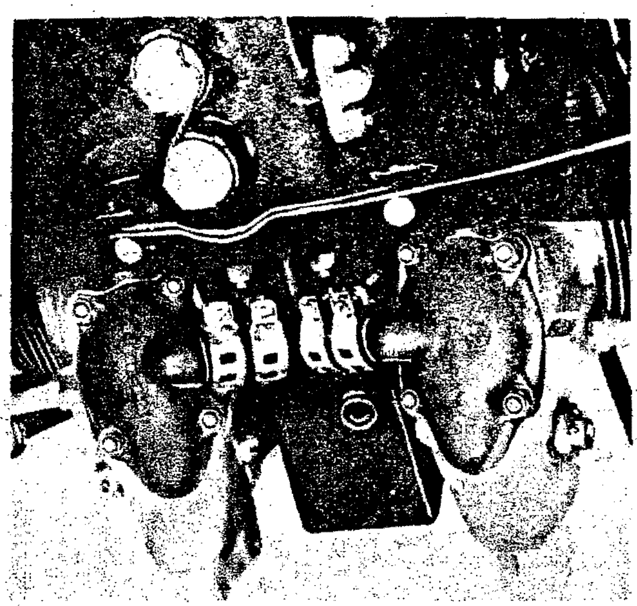


Figure 7–86. Oil Sump

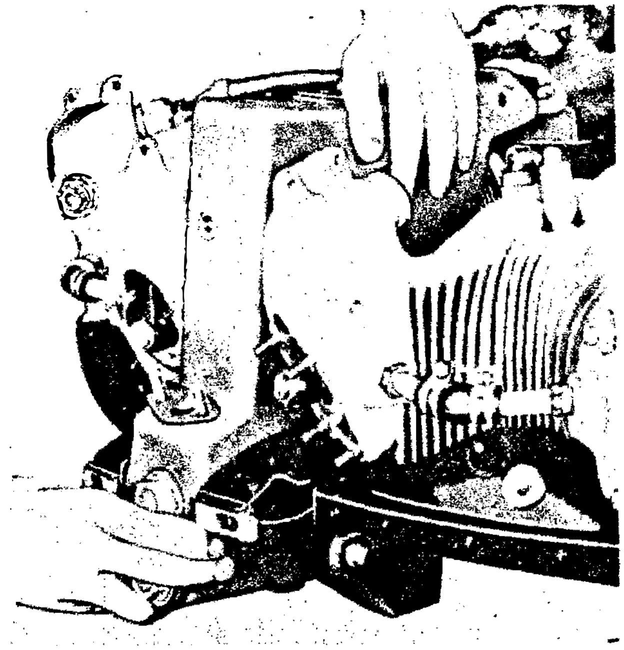


Figure 7–87. Removing Oil Sump

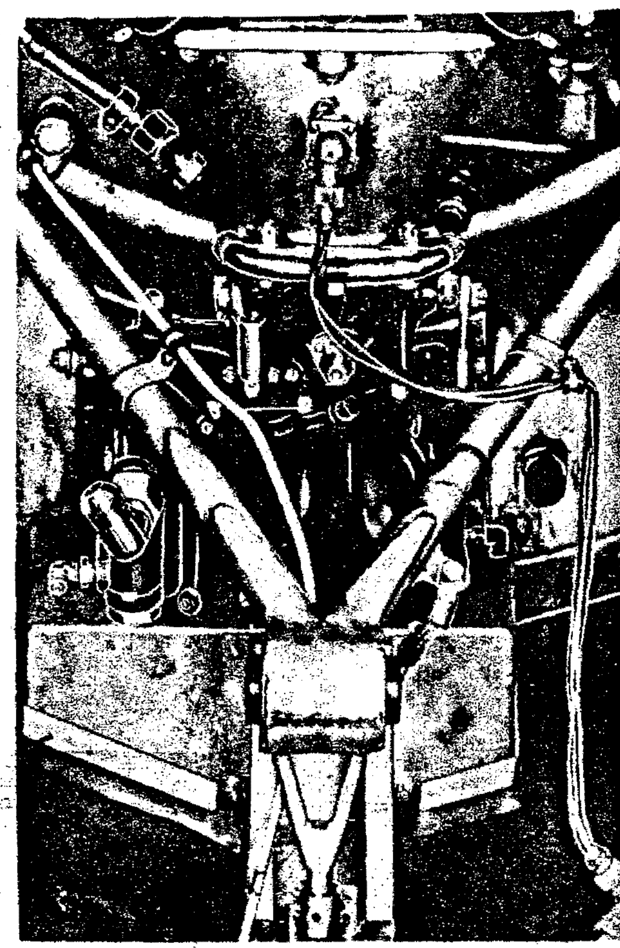


Figure 7–88. Carburetor Replacement

or a home made extractor, into the drilled center and turn out the broken stud with a wrench on the extractor. To facilitate stud removal, heat may be applied to the particular locality. If a small amount of damage is noted in the threads of the hole where the stud was removed, clean the threads with an oversize tap.

7–108. The following table illustrates the various methods of marking oversize studs for identification. The identifying mark is on the anchor end of the stud. The conical projection or green dye for .004 inch oversize studs, the conical cup or red dye for .008 inch oversize studs, and the drilled hole or purple dye for .012 inch oversize studs are the Pratt & Whitney Aircraft standard identifying marks. The other marking methods are illustrated because they are used by various vendors and may be encountered in the field.

CAUTION

When installing an oversize stud in a stud hole which goes completely through a part, make sure that the anchor end of the stud does not project beyond the hole sufficiently to cause interference with other parts. If necessary, file off the anchor end enough to ensure against such interference; then reidentify the stud with the proper oversize mark.

OVERSIZE	+.004 IN.	+.006 IN.	+.012 IN.
P. & W. A Standard	OR GREEN DYE	OR RED DYE	OR PURPLE DYE
Stamped No With Prefix	-4	+8	+12
Stamped No Without Prefix	4	8	12
Stamped or Scribed Line			
Stamped or Scribed Line			

7–109. If one or two cylinder flange studs on any one pad have failed, replace the failed studs and replace the studs on each side of the failures. If more than two studs have failed, inspect and, if necessary, lap the cylinder flange as directed in paragraph 7–74; replace all of the flange studs for that cylinder pad. Proper fit of a stud is indicated by a driving torque of 250 to 450 pound-inches. The driving torque must be within these limits; otherwise, cylinder flange stud replacement is faulty.

7–110. TORQUE RECOMMENDATIONS.

7–111. The following torque values, in pound-inches, are recommended for use during assembly of the subject Pratt & Whitney Aircraft reciprocating engines. The torque values for all nuts, bolts and screws are based on the use of a thread lubricant, such as engine oil or equivalent, except where otherwise specified or where the applicable overhaul lubrications recommend a special lubricant or surface coating. Torque values for interference fit applications such as studs, pushrod cover cylinder connectors and pipe plugs may be obtained with or without lubrication, unless otherwise specified.

7–112. Torque indicating devices should be checked daily and calibrated by means of weights and a measured lever arm to ensure accuracy. Checking one torque wrench against another is not sufficient. Some wrenches are quite sensitive as to the way they are supported during a tightening operation and instructions furnished by their respective manufacturers should be followed. Tightening should be done slowly and evenly for consistency and accuracy.

7–113. There may be certain instances, other than those included under "Specific Recommendation" paragraph 7–124, where it is obvious that the torque recommendations for tightening a nut on a bolt or stud of given size should not be used, due to the kind of material or the design of the engine parts involved. Common sense and good judgment should, of course, be used in such cases.

7–114. After a castle nut, screw, or bolt has been tightened to the proper torque, it should not be loosened to permit the insertion of lockwire or a cotterpin. If the slots in a nut or the lockwire holes in a bolt or screw are not properly aligned at the minimum torque limit, the nut, screw, or bolt should be further tightened to the next aligning position, but the maximum torque limit, if any, must not be exceeded. If this alignment cannot be accomplished without exceeding the maximum torque limits, back off the nut, screw, or bolt half a turn; then retighten. Occasionally, it may be necessary to select a new part.

7–115. Because of the necessary unconventional design of cylinder flange nut wrenches, particular care should be exercised in tightening cylinder flange nuts. The specified torque limits apply only when Pratt & Whitney Aircraft wrenches, or wrenches of identical design, are used. See that the cylinder flange nut wrench, the extension, and the torque indicating handle are so assembled that the handle is directly opposite the box end of the wrench, and apply torque by rotating the assembly as a unit. Do not let the shaft of the wrench twist to one side.

7–116. USE OF TORQUE WRENCHES WITH EXTENSIONS OR ADAPTERS.

7–117. Sometimes it is necessary to use a special extension or adapter wrench together with a standard torque wrench. In order to arrive at the resultant required torque limits, the following should be used:

T = Designed torque on the part.
E = Effective length of special extension or adapter *(See Figure 7–88A).*
L = Effective length of torque wrench.
R = Reading on scale or dial of torque wrench.
A = Distance thru which force is applied to part.

$$R = \frac{LT}{A} = \frac{LT}{L+E}$$

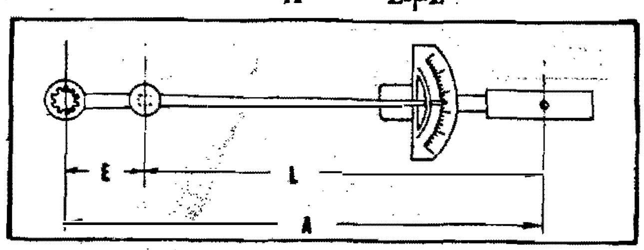


Figure 7–88A. Torque Wrench And Adapter

Example: A torque of 1440 pound-inches is desired on a part, using a special extension, having a length of 3 inches from center to center of its holes, and a torque wrench, measuring 15 inches from center of handle or handle swivel to center of its square adapter.

$$\text{Then} \quad R = \frac{LT}{L+E} = \frac{15 \times 1440}{15+3} = 1200$$

7–118. With the axis of the extension or adapter and the torque wrench in a straight line, tightening to a wrench reading of 1200 pound-inches torque will provide the desired torque of 1440 pound-inches on the part.

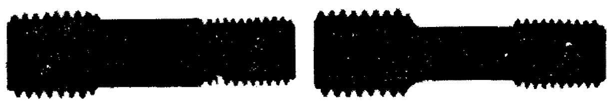
7–119. GENERAL RECOMMENDATIONS.

7–120. If a pipe plug is found to leak after it has been tightened to these limits, it should not be tightened further, but should be removed and more sealing compound applied to the threads. The plug should then be reinstalled and retightened to the desired limits.

7–121. When plugs are tightened in a hot engine, the torques recommended above should be reduced 20% owing to the different expansion characteristics of the steel plugs and the aluminum or magnesium cases.

7–122. If the torque required to drive a stud to the correct projection length should not come up to the minimum or should exceed the maximum given above another stud should be selected.

7–123. The above general recommendations should be followed with the exceptions included in the following list:

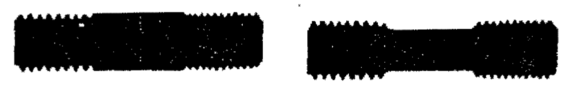


PLAIN NECKED

STEPPED STUDS

Thread Size (Nut End)	Torque Limits		
	Minimum	Maximum	
	Plain and Necked	Plain	Necked
8-36	10	30	30
10-32	15	50	45
12-28	20	75	65
1/4-28	40	125	115
5/16-24	85	260	240
3/8-24	160	500	450
7/16-20	200	800	700
1/2-20	250	1300	1150
9/16-18	425	1800	1600
5/8-18	625	2600	2400
3/4-16	1100	4600	4200

STANDARD STUDS



PLAIN NECKED

Thread Size	Driving Torque Limits		
	Minimum	Maximum	
	Plain and Necked	Plain	Necked
8-32-36	10	30	30
10-24-32	15	45	40
12-24-28	20	70	65
1/4-20-28	40	105	95
5/16-18-24	85	230	210
3/8-16-24	160	425	375
7/16-14-20	200	675	600
1/2-13-20	250	1050	950
9/16-12-18	425	1500	1400
5/8-11-18	625	2100	1900
3/4-10-16	1100	3800	3500

NUTS, BOLTS, AND SCREWS

Thread Size	Limits		Thread Size	Limits	
	Min.	Max.		Min.	Max.
8-32	15	20	3/8-24	225	300
8-36	15	20	7/16-14	325	430
10-24	20	30	7/16-20	360	480
10-32	20	30	1/2-13	500	650
12-24	35	45	1/2-20	560	750
12-28	35	45	9/16-12	700	950
1/4-20	50	70	9/16-18	800	1050
1/4-28	65	85	5/8-11	1000	1300
5/16-18	110	150	5/8-18	1150	1500
5/16-24	125	170	3/4-10	1700	2300
3/8-16	200	270	3/4-16	2000	2600

STEEL PIPE PLUGS IN ALUMINUM AND MAGNESIUM CASES

Thread Size	Torque Limits	
	Minimum	Maximum
1/16 in. A.N.P.T.	30	40
1/8 in. A.N.P.T.	30	40
1/4 in. A.N.P.T.	70	85
5/16 in. A.N.P.T.	70	85
3/8 in. A.N.P.T.	95	110
1/2 in. A.N.P.T.	140	160
3/4 in. A.N.P.T.	210	230

7–124. SPECIFIC RECOMMENDATIONS.

Engine Parts	Limits
Cylinder Flange Nuts	300 to 350 pound-inches
Dehydrating Plugs	
Cylinder	20 to 25 pound-inches
1 in. Thread and ¾ in. Thread	35 to 45 pound-inches
Palnuts	Snug; then an additional ¼ turn.
Pushrod Cover Nuts	125 to 150 pound-inches
Propeller Shaft Thrust Nut	Tighten thrust nut 250 pound-feet, then through an angle of 25° to 30°.
Rigid Bracket Mounting Nuts	400 to 450 pound-inches
Rockerbox Cover Nuts	60 to 75 pound-inches
Rockershaft Nuts	200 to 250 pound-inches
Rockershaft Caps and Nuts (Aluminum)	65 to 100 pound-inches
Sparkplugs	300 to 360 pound-inches
Sparkplug Lead Coupling	
⅝ - 24 Thread	100 to 120 pound-inches
¾ - 20 Thread	140 to 160 pound-inches
Thrust Bearing Cover Nuts	100 to 150 pound-inches
Valve Adjusting Screw Locknut	300 to 350 pound-inches

7–125. LIMITS.

7–126. These tables should be used in conjunction with the Limits and Lubrication Charts for the R-985 series engines. The symbol "T" in the Minimum and Maximum columns indicates a tight fit. The symbol "*" indicates that worn parts should be replaced if any looseness is found. The expression "Fit To" indicates that a fitting operation may be necessary at assembly to obtain the required fit. The expression "By Selection" indicates that it may be necessary to select other parts or relationships of parts to obtain the required fit. Unless otherwise specified, fits are diametrical. Reference numbers not listed in the following tables but appearing in the Limits and Lubrication Charts are required only in overhaul procedures, and are covered in TM 1-2R-R985-3.

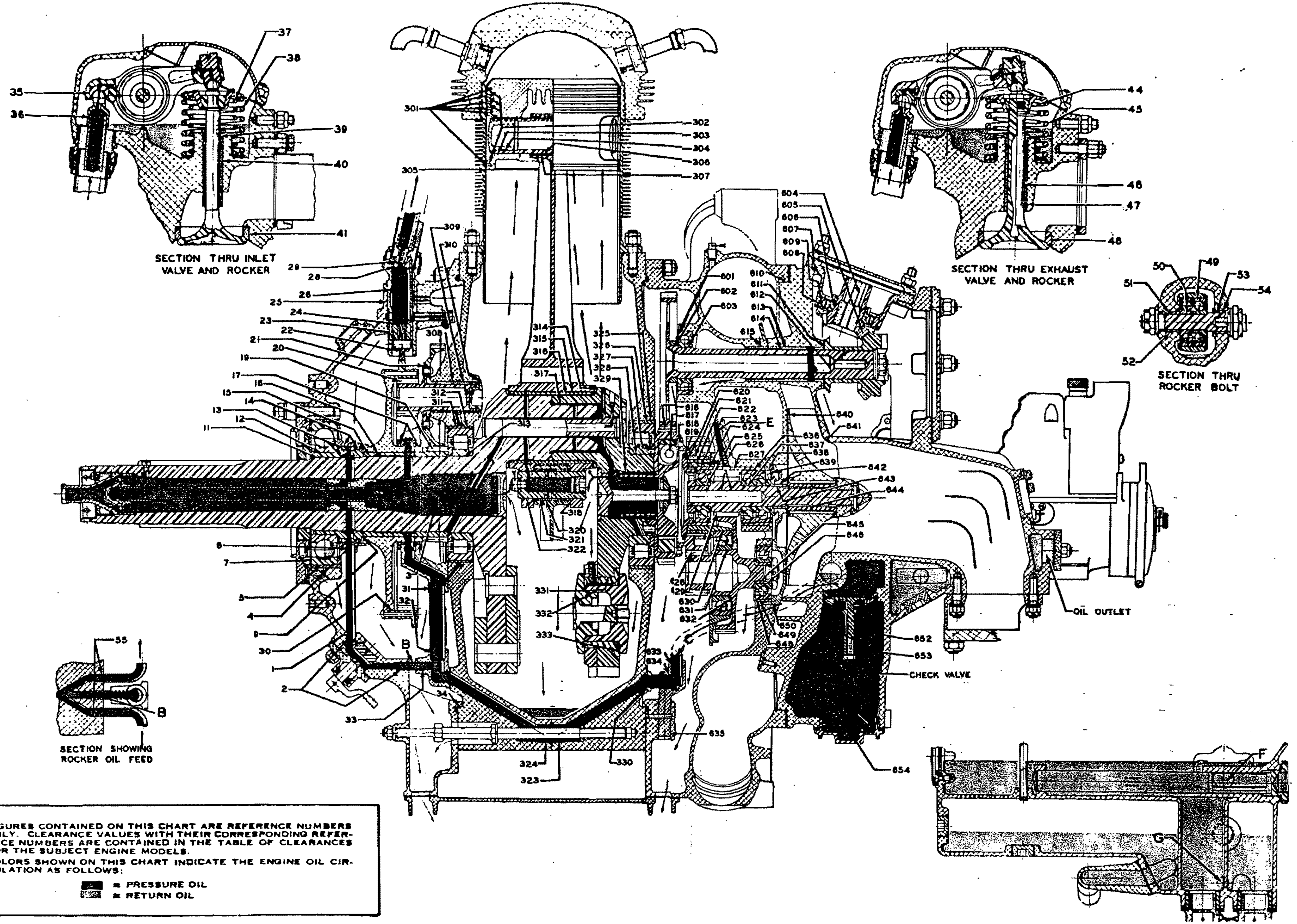
Ref. No.	Chart No.	Description	Min.	Max.	Replace
4	1	Thrust Bearing Liner — Front Case (Shrink)	.002T	.006T	*
5	1	Thrust Bearing — Bearing Liner	.0002	.002	.004
7	1	Thrust Bearing Cover Ring Pinch — Thrust Bearing Cover (Fit To)	.004T	.008T	*
8	1	Propeller Control Oil Feed Tube — Thrust Bearing Liner	.000	.0015	.003
28	1	Pushrod Ball Socket — Valve Tappet	.0005T	.0025T	*
35	1	Pushrod Ball Socket — Valve Rocker	.000	.0025T	*
36	1	Pushrod Ballend — Pushrod	.0015T	.0035T	*
39	1	Inlet Valve Guide — Valve	.0015	.004	.010
40	1	Inlet Valve Guide — Cylinder Head	.0005T	.003T	*
41	1	Inlet Valve Seat — Cylinder Head (Shrink)	.0065T	.010T	*
43	1	Cold Valve Clearance (Inlet and Exhaust)	.010	.010	
46	1	Exhaust Valve Guide — Valve	.003	.0055	.010
47	1	Exhaust Valve Guide — Cylinder Head	.0005T	.003T	*
48	1	Exhaust Valve Seat — Cylinder Head (Shrink)	.0065T	.010T	*
49	1	Rocker Bearing — Valve Rocker	.0005T	.0015T	*
50	1	Rocker Bearing — Rocker Shaft	.000	.0008	.0015
51	1	Rocker Shaft Bushing — Shaft	.000	.001	.002
52	1	Rocker Shaft Small Bushing — Cylinder Head	.001T	.004T	*
53	1	Rocker Shaft Bushing — Shaft	.000	.001	.002
54	1	Rocker Shaft Bushing — Cylinder Head	.001T	.004T	*
55	1	Rocker Oil Manifold — Front Section	.000	.002	.004

Ref. No.	Chart No.	Description		Min.	Max.
301	1	Pistonrings — End Clearance			
		Five Groove Piston, Straight Bore	Top Groove	.0225	.0295
			2nd Groove	.0225	.0295
			3rd Groove	.0225	.0295
			4th Groove	.0225	.0295
			5th Groove	.0115	.0185
		Five Groove Piston, Tapered Bore	(Rectangular and Wedge Type Rings)		
			Top Groove	.052	.062
			2nd Groove	.0515	.0585
			3rd Groove	.0515	.0585
			4th Groove	.0515	.0585
			5th Groove	.0115	.0185
			(With Chrome-Moly Barrels Using Compression Ring in Place of Scraper Ring)		
			5th Groove	.0515	.0585
302	1	Pistonring Side Clearance			
		Five Groove Piston (Straight Type Rings)	Top Groove	.007	.009
			2nd Groove	.0055	.0075
			3rd Groove	.003	.005
			4th Groove	.0035	.007
			5th Groove	.001	.0035
		Five Groove Piston (Wedge Type — Top Three Rings)	Top Groove	.002	.006
			2nd Groove	.002	.006
			3rd Groove	.002	.006
			4th Groove	.0035	.007
			5th Groove	.001	.0035
			(Wedge Type Ring Clearance is Measured with Outer Face of Ring Flush with Piston)		

Ref. No.	Chart No.	Description	Min.	Max.	Repl
303	1	Pistonpin — Piston (Light Hand Push Fit When Parts Are Oiled and at Room Temperature)			.00
304	1	Pistonpin Plug — (Service Fit)	.0015T	.00T	*
305	1	Piston — Cylinder Barrel	.018	.022	.02
306	1	Pistonpin Bushing — Pin	.0017	.0033	.00
307	1	Pistonpin Bushing — Master and Linkrod	.0045T	.006T	*
652	1	Oil Return Check Valve — Valve Guide	.0005	.0035	
702	1	Oil Pressure Relief Valve Piston — Body	.002	.006	.01(

7-127. SPRING PRESSURE.

Ref. No.	Chart No.	Description	Min.	Repl(
27	1	Valve Tappet Spring Dia. Wide .051 at 1⅝″	4#	2#
37	1	Inlet Valve Spring (Inside) Dia. Wire .154 at 1½″	53#	48#
38	1	Inlet Valve Spring (Outside) Dia. Wire .183 at 1½″	68.5#	64#
44	1	Exhaust Valve Spring (Inside) Dia. Wire .162 at 1½″	62¼#	58#
45	1	Exhaust Valve Spring (Outside) Dia. Wire .192 at ½″	79½#	75#
617	1	Impeller Spring Drive Spring Rectangular Wire at ⅞″	95#	50#
653	2	Oil Return Check Valve Spring Dia. Wire .038 at 13/16″	2¼#	1¾#
654	2	Oil Screen Retaining Spring Dia. Wire .069 at 1-3/32″	9#	5#
703	2	Oil Pressure Relief Valve Spring Dia. Wire .0625 at 1-7/16″	19#	9½#



FIGURES CONTAINED ON THIS CHART ARE REFERENCE NUMBERS ONLY. CLEARANCE VALUES WITH THEIR CORRESPONDING REFERENCE NUMBERS ARE CONTAINED IN THE TABLE OF CLEARANCES FOR THE SUBJECT ENGINE MODELS.

COLORS SHOWN ON THIS CHART INDICATE THE ENGINE OIL CIRCULATION AS FOLLOWS:

= PRESSURE OIL

= RETURN OIL

Figure 7–89. Limits and Lubrication Chart

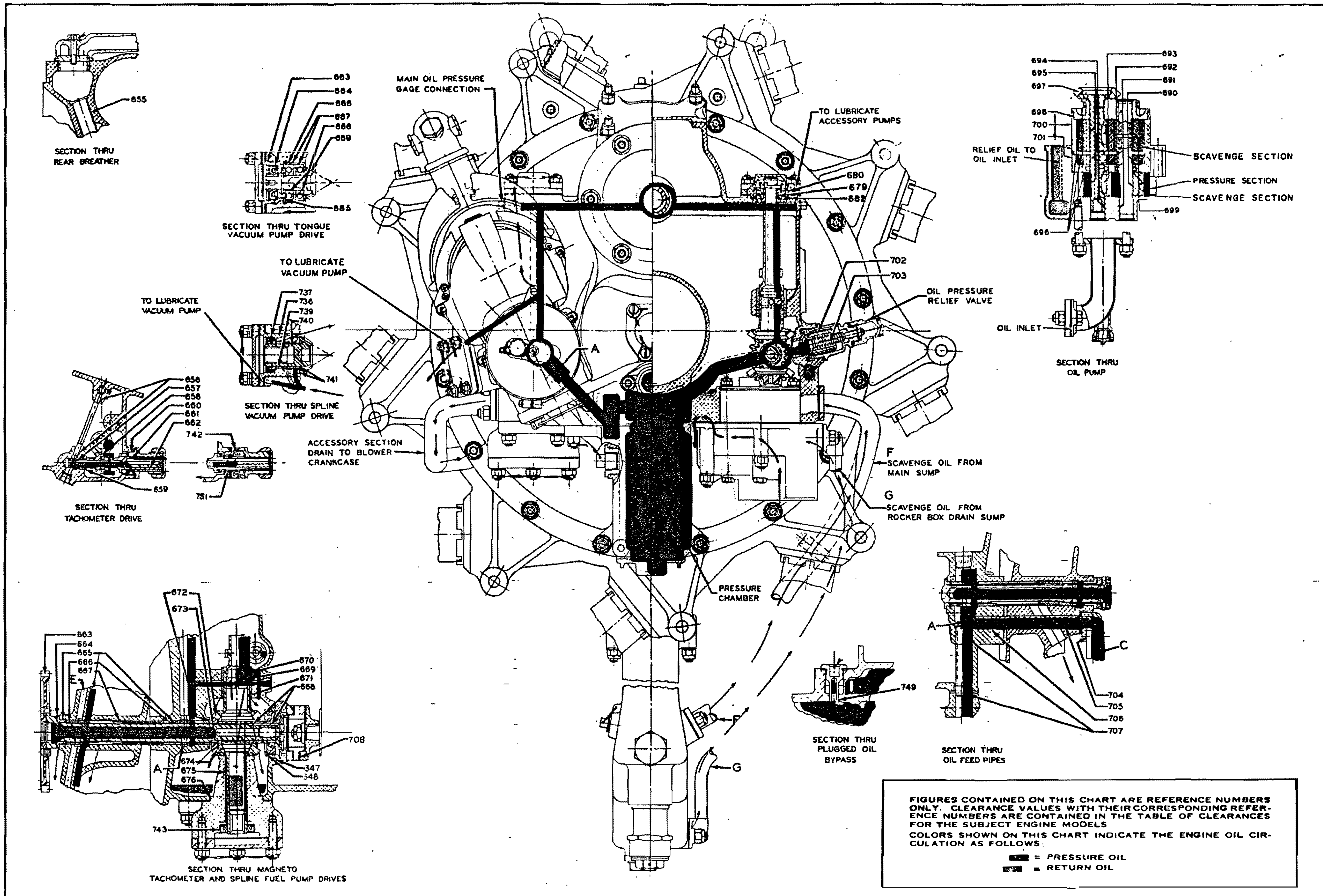


Figure 7–90. Limits and Lubrication Chart for Rear Section

SECTION VIII

TOOLS

Tool No.	*Tool Name*	*Application*	*Figure No.*
PWA-10	Holder	Lapping valves (inlet)	
PWA-11	Holder	Lapping valves (exhaust)	
PWA-37	Sling	Lifting engine	
PWA-85	Pointer	Timing engine	7–22
PWA-112	Bar	Turning crankshaft	7–22
PWA-228	Wrench	Turning oil strainer cover	
PWA-237	Wrench	Intake pipe nut	
PWA-249	Clamp	Compressing pistonrings	7–78
PWA-312–11	Indicator	Checking cylinder bore	7–70
PWA-455	Depressor	Depressing rocker	7–53
PWA-459	Compressor	Compressing valve springs	7–61
PWA-520	Eye	Lifting engine	4–27
PWA-614	Drift And Base	Removing and installing rockerbearing	7–68
PWA-671	Wrench	Removing and installing relief valve body	7–80
PWA-737	Gage	Inspecting exhaust valve	7–76
PWA-1313-T-3	Gage	Checking cylinder bore (Use with PWA-312-11)	7–70
PWA-1327	Puller	Removing oil pump	
PWA-1415	Drift	Installing oil seals	
PWA-1526	Tap	Sparkplug bushing	
PWA-1683	Wrench	Removing and installing sparkplug lead	7–24
PWA-1787	Wrench	Oil sump drain plug	
PWA-1791	Pliers	Removing and installing pistonrings	7–72
PWA-1886	Wrench	Removing and installing ignition manifold	
PWA-1937-20	Crimper	Crimping ignition cable ferrule	

Tool No.	*Tool Name*	*Application*	*Figure No.*
PWA-2006	Wrench	Removing and installing cylinder	7–59
PWA-2151-1	Drift	Removing pushrod ballend	
PWA-2199	Lap	Cylinder barrel flange	7–69
R41-W-3570	Wrench	Torque indicating	7–79
R41-A-45	Adapter	Torque wrench	7–79
PWA-2285	Drift	Installing fuel pump gear oil seal	
PWA-2388	Hook	Lifting engine	4–27
PWA-2397	Wrench	Removing cylinder	
PWA-2398	Handle	Removing cylinder	7–59
PWA-2399	Wrench	Removing cylinder	7–59
PWA-2411	Handle	Removing cylinder	7–59
PWA-2417	Indicator	Timing magnetos	
PWA-2488	Holder	Holding linkrod	
PWA-2630-20	Gage	Inspection cylinder flange	
PWA-2834	Holder	Holding masterod	
PWA-3145	Puller	Removing intake pipe	
PWA-3168	Wrench (7/8)	Sparkplug	7–26
PWA-3201-1	Gage	Inspecting pistonrings	7–73
PWA-3252	Plug	Sparkplug hole vent plug	
PWA-3372	Compressor	Hose clamp	
PWA-3639	Wrench	Removing pushrod cover nuts	7–52
PWA-3762	Puller	Removing oil seals	
PWA-3926	Remover	Removing exhaust port cover	
R85-I-4075	Indicator	Indicating spark advance	7–16
PWA-4152	Driver	Adjusting valves	7–12
PWA-4251-10	Pusher	Removing pistonpin	
R41-G-415	Gage	Adjusting valves	7–12
PWA-4877	Puller	Removing and installing pushrod ballend	7–54
PWA-5072	Wrench	Removing intake pipe	7–49
PWA-5630	Wrench	Pushrod gland nut	
R85-P-31300	Plate	Mounting engine in R-85-S-62000 stand	4–7
R-85-S-62000	Stand	Mounting engine	4–7

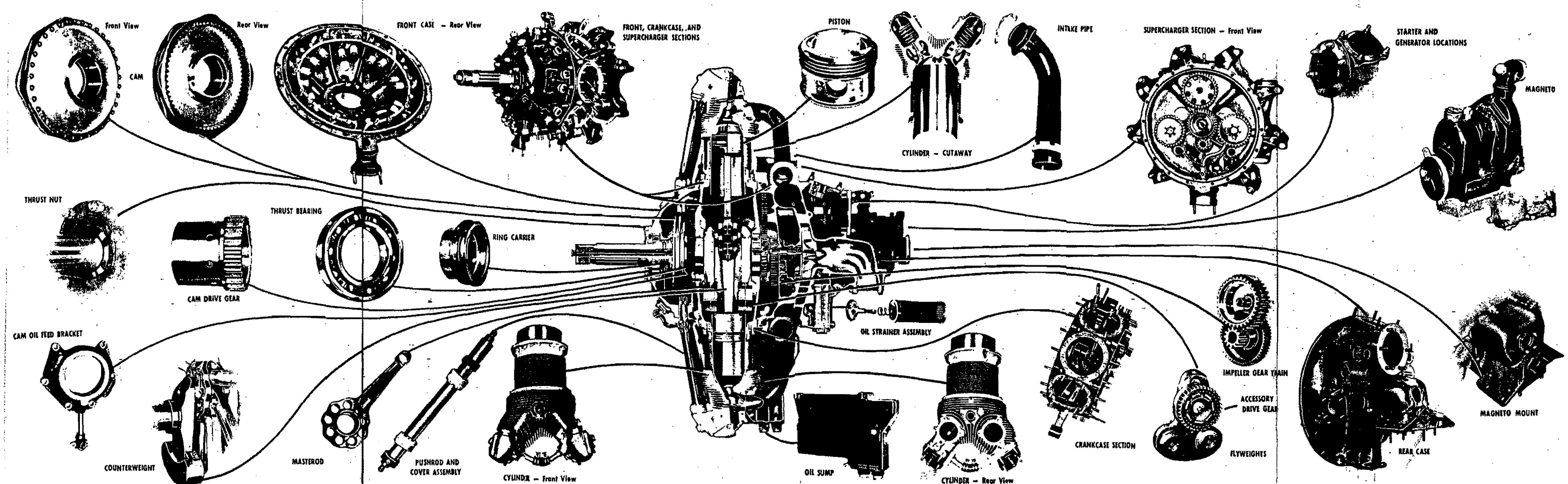


Figure 3. Sectional View of Engine